AD A153666

AD-E401 312

CONTRACTOR REPORT ARLCD-CR-85002

PRODUCT IMPROVEMENT PROGRAM FOR THE M577 FUZE--VOLUME 1, REDESIGNED TIMER

TERRY F. SLAGLE
A. LUCILLE MEISSNER
HAMILTON TECHNOLOGY, INC.
P.O. BOX 4787
LANCASTER, PA 17604

THOMAS W. PERKINS, PROJECT ENGINEER
EDWINA CHESKY, PROJECT LEADER
ARDC

MARCH 1985

U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
LARGE CALIBER WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Contractor Report ARLCD-CR-85002	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRODUCT IMPROVEMENT PROGRAM FOR THE M577 FUZE--VOLUME 1, REDESIGNED TIMER		5. TYPE OF REPORT & PERIOD COVERED Final June 1979 to April 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Terry F. Slagle, Hamilton Technology, Inc. A. Lucille Meissner, Hamilton Technology, Inc. Thomas W. Perkins, Project Engineer, ARDC Edwina Chesky, Project Leader, ARDC		8. CONTRACT OR GRANT NUMBER(s) DAAK10-79-C-0169
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hamilton Technology, Inc. P.O. Box 4787 Lancaster, PA 17604		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task 3
11. CONTROLLING OFFICE NAME AND ADDRESS ARDC, TSD STINFO Div (SMCAR-TSS) Dover, NJ 07801-5001		12. REPORT DATE March 1985
		13. NUMBER OF PAGES 89
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) ARDC, LCWSL Nuclear and Fuze Div (SMCAR-LCN-T) Dover, NJ 07801-5001		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M577 fuze
Timer
Die cast plates

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this project was to redesign the timer gear train components to decrease the manufacturing cost of the M577 fuze. In addition, methods of using the scroll movement as a means of measuring the timer output were investigated.

In the proposed design, the ring gear used to transmit the torque from the mainspring was replaced by an external drive gear mounted on the scroll. This

(cont)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (cont)

change eliminated one part and simplified another. Three of the plates were redesigned as die castings; two of these were combined into one plate.

CONTENTS

TABLES

FIGURES

INTRODUCTION

The objective of Task #3 was to redesign the timer gear train components to optimize or reduce the number of gear passes and stacked plates. In the current design a ring gear transmits the torque from the mainspring to the timer gear train. The feasibility of using an external gear to drive the timer gear train was investigated. Reducing the number of components and changing the manufacturing process for the plates were pursued. In addition, methods of utilizing the scroll movement as a means of measuring the timer output were investigated.

DISCUSSION

Description of Design Change

The current timer design uses a ring gear and support to transmit the torque from the mainspring to the gear train. In the proposed design, the ring gear is replaced by an external drive gear mounted on the scroll, thus eliminating the ring gear support and epoxy. The complicated ring gear shaft is replaced by a straight pin. Number 1 and 2 gear and pinion assemblies are retained in the proposed design but are redesigned and relocated to accommodate the external drive gear. (See Figure 1.) The current #1 pinion is retained, but the #2 pinion is redesigned to mate with the external drive gear. Since the change from an internal to an external drive gear causes the direction of the torque transmitted to the #2 pinion to be reversed, the torque at the escape wheel is reversed. The present escape wheel and lever are used, but they are both inverted to reverse the direction of the escapement. The direction the balance wheel is detented to start the clock has not been changed for the units tested so far. Since the direction of the escapement is reversed, consideration to reversing the direction of the balance wheel detent should be considered.

The gear train was designed to have nearly the same ratio as the present gear train in order to avoid making large changes in the balance frequency. Tooth counts and ratios of the present and proposed gear train are shown in Table 1. The decrease of the gear ratio in the proposed design necessitates changing the beat rate from 80.74 to 80.18 beats per second.

Table 1. Comparison of gear train ratios

	Present	Proposed
Drive Gear	53	43
#2 Pinion	8	8
#2 Gear	37	39
#1 Pinion	8	8
#1 Gear	31	36
Escape Pinion	8	8
Ratio	118.73	117.91

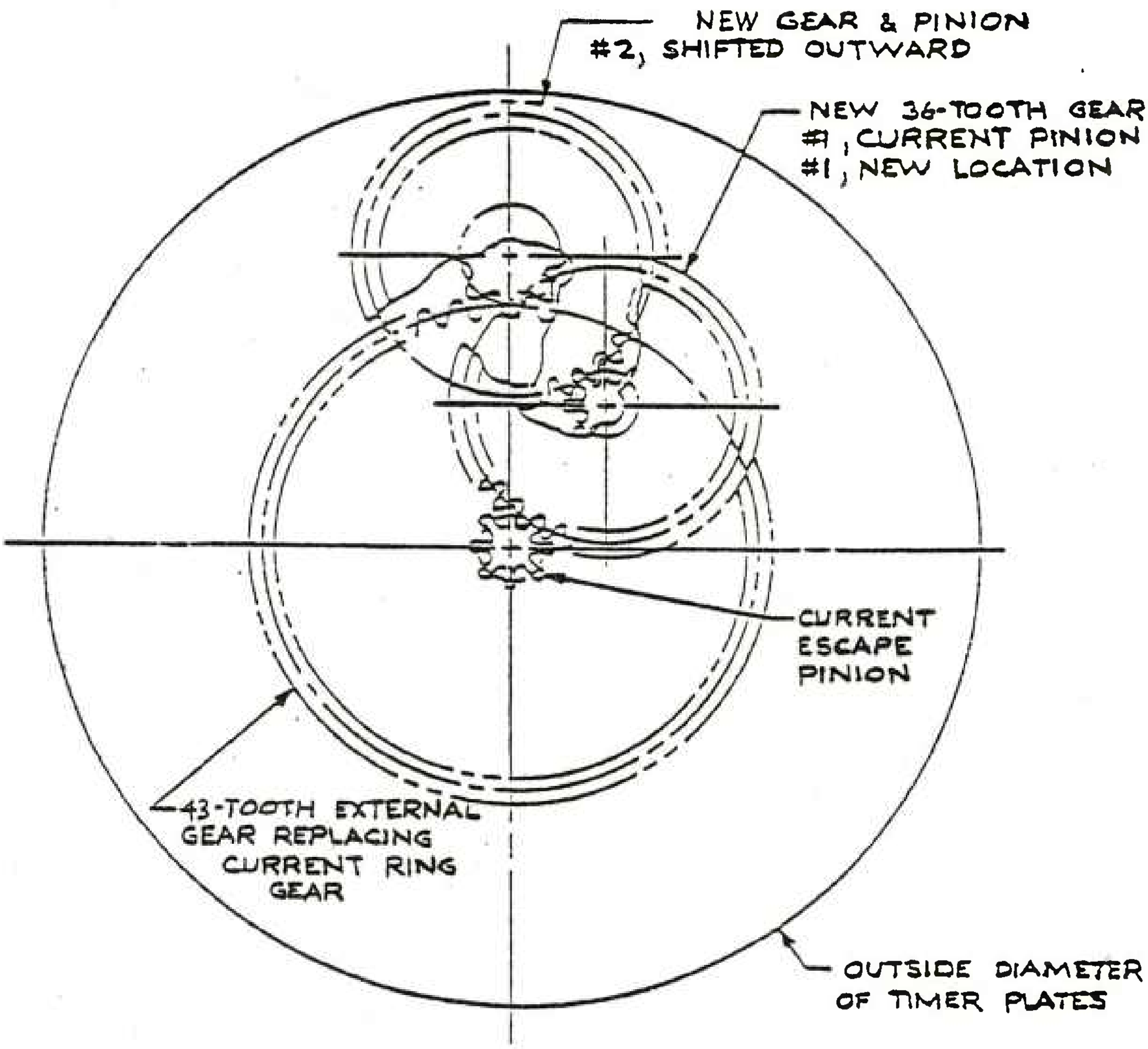


Figure 1. Revised gear train

In the current design, plate no. 6, made from wrought aluminum, houses the lower pivots of the escape wheel and both gear and pinion assemblies; it also houses the upper pivot of the drive gear. Plate no. 5, also wrought aluminum, is used only as a spacer. In the proposed design, plates no. 5 and 6 are combined into one aluminum die cast plate, known as the lower plate. This plate performs the same functions as plates no. 5 and 6 do in the current design; in addition, a hub has been added which aids in retaining the scroll assembly to the gear train. (See Figure 2.)

The current wrought aluminum no. 1 plate is replaced by an aluminum die cast plate of similar design. The method of securing the setting ring gear in the no. 1 plate was modified in order to eliminate the subassembly which consists of the two setting ring gears and dowel pins. Tabs which prevent the setting ring gears from rotating are added to the no. 1 plate. A roll stake is used to hold the setting ring gears in the plate. Since die cast aluminum has less strength than wrought aluminum, changes to the design were made to decrease the load on the no. 1 plate and increase its strength. The list of parts with a description of the change is given in Table 2.

No. 1 Plate Development

A zinc die casting duplicating the present machined no. 1 plate was first tried. Air gun tests indicated that the zinc die cast no. 1 plate could not withstand 30,000g setback. The no. 1 plate showed significant damage from the load applied by the timer housing. Fuzes, incorporating a new timer housing under development at the time, along with the zinc die cast no. 1 plate, were air gun tested. There was no visible damage to the no. 1 plates, but the units did not run properly after the test. The dowel pins and bushing which had been pressed into the no. 1 plate were loose after the air gun test. Dowel pins that had been pressed in timers three months earlier but not air gun tested were also retested for push off. These dowel pins, which had held a 40 pound push off at the time of assembly, pushed off with a load of 8 to 30 pounds on the retest. A short term creep test with a 300% overload performed on the zinc lower plate indicated an unacceptable creep rate. This indicates a problem of creep at an unacceptable rate in the zinc plate. Consequently, using a zinc die cast no. 1 plate and lower plate were dropped from further consideration.

Since die cast aluminum exhibits much less creep than die cast zinc, it was decided to substitute die cast aluminum for zinc in both the no. 1 plate and lower plate. It was determined that the same die could be used to cast the aluminum plates as was used for the zinc plates. Units with die cast aluminum no. 1 plates and lower plates were built and air gun tested. The lower plate withstood the air gun test satisfactorily. Four of the ten no. 1 plates fractured from the load of the timer housing, and loose dowel pins were still present.

Table 2. List of changed parts

Part Description	Current Part No.	Proposed Part No.	Description Of Change
Timer Assembly	9236634	SK5968	Redesigned gear train and changed plates.
Timer Scroll Assy.	9236690	SK5394	Changed configuration and assembly operations
Timing Scroll	9271993	SK5914	Added spline for drive gear
Shaft & Support Assy.	9236709	-	Deleted
Ring Gear Supp. & Shaft Assy.	9236708	-	Deleted
Ring or Drive Gear Shaft	9236695	11786101	Simplified part
Ring Gear Support	9236710	-	Deleted
Ring or Drive Gear	9236694	11786103	Changed to external gear
Pinion #2	9236680	11786102	Increased length and changed tooth form
Gear #2	9236679	SK5417	Changed number of teeth
Gear #1	9236676	SK5416	Changed number of teeth
Escape Wheel & Pinion Assy.	9236672	SK5412	Escape wheel assembled on opposite side
Lever Assy.	9236661	SK5410	Lever assembled on opposite side
Lower Plate	-	11786100	Combined plates no. 5&6 into die casting
Plate No. 6	9236681	-	Deleted
Plate No. 5	9236671	-	Deleted
Plate No. 4	9236669	SK5379	Changed hole locations
Plate No. 3	9236660	SK5378	Changed hole locations
Plate No. 1 Assy.	9236635	SK5971	Changed two assembly operations
Setting Ring Gear Assy.	9236640	-	Deleted
Ring Gear Dowel Pin	9236641	-	Deleted
Setting Ring Gear	9236642	SK5912	Eliminated two slots and hole; changed other two slots
Plate No. 1	9236636	SK5889	Changed to die casting and altered configuration
Dowel Pin	9236637	SK6357	Added knurl
8alance Wheel, Staff & Hairspring Assy.	9236647	SK5967	Changed beat rate
Spacer	9236566	SK6216	Reduced thickness
Sleeve	9236631	SK6276	Changed location of retaining ring groove
Spacer (.025)	-	SK6358	Added shim between spring washer and timing housing
Plate No. 4 & Bearing Ass'y	9236668	SK5439	Changed hole locations in No. 4 Plate
Gear #2 and Pinion Ass'y	9236678	SK5419	Changed gear and pinion
Gear #1 and Pinion Ass'y	9236675	SK5421	Changed gear

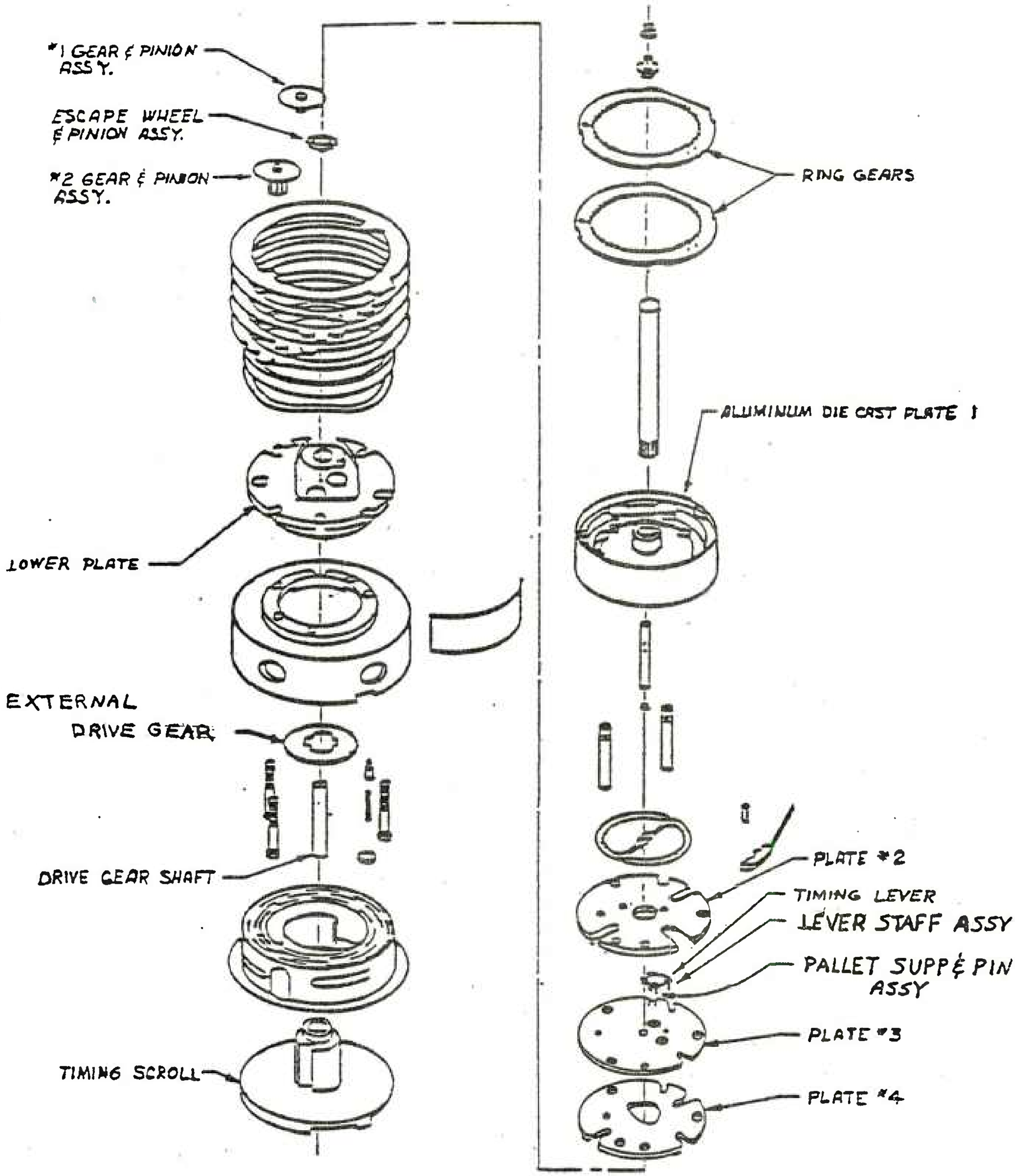


Figure 2. Revised timer redesign

Additional testing and development was performed on the aluminum die cast no. 1 plate. The results of this work showed the following:

1. Normalization improves the strength characteristics of the no. 1 plate and allows the use of a ring stake in the no. 1 plate to retain the ring gear. Static testing showed that the normalized plates can safely withstand 2,000 pounds versus 1,500 pounds without normalizaion.

2. The no. 1 plate thickness was increased .025 inch to increase its strength in the well area.

3. Tolerance studies showed that the clearance between the no. 1 plate and timer housing assembly could be increased from - 0.0125 to 0.0375 inch by removing the counterbone in the no. 1 plate and raising the timer housing by .025 inch.

4. The dowel pins used in the no. 1 plate assembly were embossed with a diamond knurl and the diameter of the dowel pin holes was decreased to increase the interference between the pin and the plate. The engagement length of the dowel pins in the no. 1 plate was increased by .053 inch.

Redesigned no. 1 plates were statically tested and air gun tested with satisfactory results.

Design of Drive Gear and #2 Pinion

A drive gear and #2 pinion were first designed using the clock gear form, but the strength of the pinion teeth was not strong enough to carry the mainspring torque with overwind. The involute tooth form was investigated. While this form is less smooth in its operation than the clock form, it is adequate for this application.

The redesigned timer requires the use of an eight tooth pinion. Because of the low number of teeth required, tooth form modification is necessary to provide sufficient contact ratio and tooth strength. Four standard addendum modification systems were explored to determine which is best suited for this application. Both the enlarged center distance with long addendum pinion and the long and short addendum systems of the AGMA 207.04 and 207.06 were compared.

Both of the above standards use conventional hob withdrawal techniques to achieve a long addendum pinion, differing only in the amount of hob withdrawal recommended. This long addendum pinion is paired with either a short addendum gear on standard centers or a standard addendum gear on enlarged centers. The results of this investigation are tabulated in Table 3.

Table 3. Gear data for systems investigated

	Long/Short Addendum		Enlarged Center Dist.	
	AGMA 207.04	207.06	207.04	207.04
Cir. tooth thickness (@ generating pressure))				
pinion	1.9581"	2.09854"	1.9581"	2.09854"
gear	1.1835"	1.04305"	1.5708"	1.5708"
Contact Ratio	1.19	1.16	1.19	1.16
Total Path of Contact	3.5152"	3.4332"	3.5152	3.4277"
Approach Action	2.5602"	2.6642"	2.3464"	2.3840"
Recess Action	.9550"	.7690"	1.1688"	1.0437"
Operating Center Dist.	25.5000"	25.5000"	25.9978"	26.1648"
Max. Allowable Increase in Cent. Dist. (CD)	+.3146"	+.1685"	+.3185"	+.1964"
Operating Pressure)	20.00°	20.00°	22.82°	23.68°
Form Factor (Y)				
pinion	.401	.508	.401	.508
gear	.318	.285	.413	.413

The design selected is the long addendum pinion of AGMA 207.04 used in combination with a standard gear on enlarged centers. This combination was selected because it affords the greatest center distance separation tolerance and gear tooth strength. The actual strength of the pinion using enlarged centers is still greater than the gear strength because of the differing materials and face widths (see Appendix B).

The redesigned drive gear must bear a greater load than its predecessor because the external gear contacts the #2 pinion closer to the center of the timer. Since the radius to the point of loading is decreased, the load must be increased to support the same torque. The redesigned drive gear made of .040 thick beryllium copper supports a 150% overload beyond the mainspring torque (see Appendix B).

A comparison was made between the strength of the present and proposed designs. Using the involute tooth form and increased tooth width, it was determined the proposed design has a greater overload capacity than the present design.

Scroll Movement Measurement

Several methods of metering the scroll movement as a means of measuring timer output were investigated. The intent of this investigation was to reduce inspection costs.

The first method attemped measured the time for the scroll to rotate one revolution using a microswitch to start and stop the time measuring device. This measure was taken simultaneously with a beat rate reading over fifty seconds. The two measurements agreed within .1%. This method provides an accurate measurement of timer output, but it provides no inspection cost reduction.

The second method attempted used an optical device instead of a microswitch to start and stop the time measuring device. A fixture containing a disk with a pin engaging the scroll so the disk rotates along with the scroll was used. Grooves were machined and inked on the disk one degree apart. Every time the disk passed by the optic probe, the time measuring device started and stopped alternately. A digital oscilloscope was used to measure the time. The results were compared with the beat rate reading taken over five seconds. The two measurements agreed within 1%. Measurement of the scroll movement over a small angle would save inspection time and therefore labor costs. However, the information obtained would represent timer performance over a small period of time which is not desirable.

Using the scroll movement as a means of measuring timer output is technically feasible. However, this method reduces inspection costs only by decreasing the monitoring period. Decreasing the monitoring period may not be consistent with good quality timer production.

TESTING

Spin Test

Ten units, consisting of a die cast combined no. 5 and 6 plate and redesigned gear train, were built and centrifuge tested from 13,000 to 30,000 RPM. The beat rate and amplitude were recorded at various RPM intervals until the maximum speed was reached at which the timer would no longer operate. The maximum speed at which the timers would operate varied from 24,000 to 28,000 RPM. Test data showed that the timers held a consistent frequency until 15,650 RPM; then the frequency decreased. The results of the test are shown in Table 4.

A second spin test was performed on ten units with the aluminum die cast no. 1 plate, one piece pallet pin and lever staff assemblies, and the redesigned timer. Three control units were also tested. The timers were centrifuge tested from 13,000 to 30,000 RPM concentrically and eccentrically by .030 inches. The timer redesign units operated in the concentric and eccentric spin tests at spins up to 30,000 RPM. The control units operated at 30,000 RPM in the concentric spin test, but during the eccentric spin test the timers stopped operating between 25,000 and 30,000 RPM. Test results are shown in Tables 5 and 6.

Air Gun Tests

Six air gun tests were performed at various stages of development of the die cast no. 1 plate and redesign of the timer.

Seven units, containing zinc die cast no. 1 and lower plate and redesigned gear train, were built and air gun tested at 30,000 to 32,000g. Three were tested at ambient temperature and four at -50^{o}F. The no. 1 plate had deformation damage in the ambient units and cracks in the cold units. Push off tests on the dowel pins were performed after the air gun tests with unsatisfactory results. The timers did not run after the test, but the timers ran satisfactorily when the no. 1 plate assemblies were replaced. This indicates the die cast lower plate and gear train were not damaged.

Fuzes incorporating a new timer housing along with die cast no. 1 plates, as well as fuzes with a standard timer housing and die cast zinc no. 1 plates, were air gun tested from 27,000 to 36,000g. In the units with the standard timer housing, the no. 1 plates were cracked. In the units with the new timer housing, there was no visible damage to the no. 1 plate, yet these units did not run properly. Upon further examination, it was seen that the dowel pins which had been press fit in the no. 1 plate were loose, which is the likely cause of the failure of the timers to run properly. Further testing indicated a problem of creep in the zinc.

Because of the creep problem with the zinc die castings, the die casting material for both the no. 1 plate and lower plate was changed to aluminum. Ten units with die cast aluminum no. 1 plates and lower plates along with the redesigned gear train were air gun tested from 27,000 to 32,000g at an ambient temperature. Four out of ten timers functioned after the test. Examination of the no. 1 plate assembly revealed cracks in four units and loose dowel pins in five units. Results are given in Table 7.

Twelve units, with the counterbore of the aluminum die cast no. 1 plate removed and increased clearance between the timer housing and the no. 1 plate, were air gun tested from 29,000 to 37,000g. Nine out of twelve timers functioned after the test. The three timers that did not function were tested in excess of 30,000g. Unit by unit results are given in Table 8.

After the design of the aluminum die cast no. 1 plate was finalized, a fifth air gun test from 22,000 to 32,000g at -40^{o}F was performed on twenty units. Ten of these units had a standard timer movement, and ten units had the redesigned timer movement. Three out of ten timers with the standard clock movement ran after the test. Five of the ten timers with the redesigned timer movement ran after the test. Failure of the clocks to run was attributed to loose dowel pins which was caused by normalizing the no. 1 plates after the dowel pins were assembled rather than before as was done in the previous air gun units. Test data are shown in Table 9.

Ten units with an aluminum die cast no. 1 plate and lower plate, knurled dowel pins, timer redesign movement, and Westclox escapement were air gun tested from 24,437 to 31,076 g's at ambient temperature. Four out of ten timers ran after the test. Four timers had one dowel pin loose; three of these timers also had a crack in the no. 1 plate. Although the no. 1 plate assembly still showed damage after the test, these results are an improvement over previous air gun test results. Unit by unit results and observations are shown in Table 10.

Jolt and Jumble Test

Twelve fuzes with the aluminum die cast no. 1 plate, redesigned timer, and one piece pallet pin and lever staff assemblies were built and tested per MIL-STD-331, Tests 102.1 and 101.2. All units were examined after testing and were found to satisfy the criteria of 4.5.16 in MIL-F-50983.

Forty-Foot Drop Test

Five fuzes with the aluminum die cast no. 1 plate, redesigned timer, and one piece pallet pin and lever staff assemblies were built and tested per MIL-STD-331, Test 103. All units were examined after testing and were found to satisfy the forty-foot drop requirements in MIL-F-50983.

Five-Foot Drop Test

Ten fuzes with the aluminum die cast no. 1 plate, redesigned timer, and one piece pallet pin and lever staff assemblies and ten control fuzes were built and tested per MIL-STD-331, Test 111.1 Two test and two control units were dropped in each of the five fuze positions stated in MIL-STD-331, Test 111.1. All test and control fuzes had functioning timers after the test, but in two of the test units and in two of the control units, the setback pin in the timer had gone down.

A second five-foot drop test was performed to examine the setback pin movement at two test positions. A total of ten timer redesign and ten control units were tested. Five units from each group were dropped in a base down position and five units from each group were dropped in a 45° base down position. All previously reported setback pin failures had occurred at either of the two tested positions. All units were X-rayed immediately after they were dropped for setback pin evaluation. The setback pin remained down in three timer redesign units and one control unit. One control and two timer redesign units failed in the base down position and one timer redesign unit failed at the 45° base down position.

Ballistic Tests Using Redesigned Gear Train

One-hundred-five fuzes, containing the aluminum die cast lower plate and redesigned gear train and 105 control fuzes were built, shipped to Yuma Proving Grounds, and ballistically tested in February 1982. Round by round data were reported by U.S. Army Yuma Proving Grounds in Firing Report No. 82-PI-0046-L5. Because of duds and differences in the mean times between the test and control units, it was decided to repeat some of the testing. The results of the testing are shown in Table 11.

Fifty test and fifty control fuzes were ballistically tested in the three phases that had questionable results in the previous test. No duds occurred in either test or control units, and there were no significant differences in the mean times between the test and control units. Round by round data were reported by U.S. Army Yuma Proving Grounds in Firing Report No. 82-PI-0255-L5. Table 11 shows a summary of the results from both ballistic tests.

Ballistic Tests Using Aluminum Die Cast No. 1 Plate

Thirty-five fuzes, containing the aluminum die cast no. 1 plate, and 35 control fuzes were built and shipped to Yuma Proving Grounds for ballistic testing. All test units functioned properly with acceptable times. A summary of the results is shown in Table 12. Round by round data were reported by the U.S. Army Yuma Proving Grounds in Firing Report No. 82-PI-0120-L5.

Combination Ballistic Test

Seventy-five fuzes, containing the redesigned gear train, aluminum die cast no. 1 plate, and one piece lever pallet pins and support, and 75 control fuzes were built and shipped to Yuma Proving Grounds for ballistic testing. Three duds occurred in the test units, one in each of three phases. Three duds were possibly caused by failure of the timer setback pin to go down. Modifications to the lower plate are being made to eliminate this problem. A summary of the test result is shown in Table 13. Round by round data were reported by the U.S. Army Yuma Proving Grounds in Firing Report No. 83-PI-0032-L5. Additional ballistic testing with this fuze configuration will be performed as part of Contract DAAK10-80-C-0063, Task 4.

Table 4. Spin test I

TIMER#	0 RPM BEFORE SPIN TEST BEAT RATE (Beats/Sec.)	0 RPM BEFORE SPIN TEST AMPLITUDE (Degrees)	13,000 RPM BEAT RATE (Beats/Sec.)	13,000 RPM AMPLITUDE (Degrees)	15,000 RPM BEAT RATE (Beats/Sec.)	15,000 RPM AMPLITUDE (Degrees)	22,000 RPM BEAT RATE (Beats/Sec.)	22,000 RPM AMPLITUDE (Degrees)	25,000 to 30,000 RPM BEAT RATE (Beats/Sec.)	25,000 to 30,000 RPM MAX. SPEED CLOCK RAN	0 RPM AFTER SPIN TEST BEAT RATE (Beats/Sec.)	0 RPM AFTER SPIN TEST AMPLITUDE (Degrees)
1	80.17	133	80.21	115°	80.23	115°	80.33	(2)	80.18	25,000	80.00	137
2	80.24	115	80.06	112°	80.21	112°	80.35	100°	79.82	25,000	80.15	119
3	80.08	130	80.03	118°	80.02	120°	79.86	(2)	79.64	28,000	79.77	132
4	80.18	139	80.17	115°	80.12	112°	80.30	70°	79.41	24,000	80.02	142
5	80.23	130	80.32	118°	80.16	115°	80.14	65°	80.13	25,000	80.03	144
6	80.27	124	80.24	115°	80.26	115°	80.34	85°	80.33	25,000	80.13	124
7	80.24	133	80.30	100°	80.31	95°	80.13	75°	77.34	24,000	80.09	140
8	80.17	117	80.17	95°	80.10	92°	79.71	(2)	Stopped	24,000	80.09	132
9	80.28	127	80.23	112°	80.22	96°	80.11	65°	80.06	25,000	80.11	136
10	80.16	125	80.14	90°	79.86	90°	70.76	50°	Stopped	24,000	80.01	138

1. Beat rate range for the timer redesign is 80.08 beats/second to 80.28 beats/second.

2. Test machine did not record data during these tests.

Table 5. Spin test II (concentric)

	0 RPM BEFORE SPIN TEST		13,000 RPM		15,000 RPM		22,000 RPM		25,000 to 30,000 RPM		0 RPM AFTER SPIN TEST	
TIMER#	BEAT RATE (Beats/Sec.	AMPLITUDE Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)
1	80.20	124	80.08	85	80.16	115	80.16	120	(3)	(3)	80.10	124
2	80.16	126	80.11	125	80.11	123	80.09	120	79.61	120	80.15	126
3	80.11	124	79.93	129	79.91	129	79.91	130	79.76	115	80.08	119
4	80.17	122	80.03	130	80.02	130	80.01	130	79.98	130	80.11	120
5	80.10	122	79.94	130	79.89	135	79.78	135	79.71	125	80.24	113
6	80.16	129	80.04	131	80.06	137	80.08	132	79.91	139	80.04	126
7	80.13	126	79.96	135	79.93	138	79.87	138	79.78	130	79.93	133
8	80.17	120	79.91	129	79.87	130	79.82	130	79.78	130	80.07	119
9	80.23	115	80.02	130	80.01	131	79.93	130	79.85	127	80.21	102
10	80.18	129	80.09	128	80.08	130	80.03	133	80.00	138	80.09	124
11C	80.67	117	80.62	130	80.62	129	80.61	129	80.50	138	80.57	119
12C	80.70	120	80.59	120	80.60	122	80.47	121	80.27	140	80.61	120
13C	80.69	119	80.63	125	80.61	130	80.62	132	80.17	125	80.61	117

1. Beat rate range for the timer redesign is 80.08 beats/second to 80.28 beats/second.
2. Timer numbers 11C, 12C, 13C are control units.
3. Test machine did not record data during these tests.

Table 6. Spin test II (eccentric)

TIMER#	0 RPM BEFORE SPIN TEST		13,000 RPM		15,000 RPM		22,000 RPM		25,000 to 30,000 RPM		0 RPM AFTER SPIN TEST	
	BEAT RATE (Beats/Sec.	AMPLITUOE Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUOE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUOE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Oegrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Oegrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)
1	80.20	124	80.05	132	80.09	135	80.07	132	79.97	138	80.10	124
2	80.16	126	80.16	125	80.16	125	80.05	122	79.78	128	80.15	126
3	80.11	124	79.96	130	79.96	130	79.89	132	79.96	125	80.08	119
4	80.17	122	80.04	130	80.10	130	80.18	120	79.96	125	80.11	120
5	80.10	122	80.16	120	80.16	125	80.16	122	80.16	130	80.24	113
6	80.16	129	80.16	130	80.16	130	80.08	125	80.07	130	80.04	126
7	80.13	126	80.16	125	80.16	125	80.16	122	80.13	130	79.93	133
8	80.17	120	79.96	130	79.99	130	80.13	120	80.14	130	80.07	119
9	80.23	115	80.09	130	80.09	125	80.02	120	79.51	125	80.21	102
10	80.18	129	80.11	130	80.18	130	80.18	130	79.68	128	80.09	124
11C	80.67	117	(3)	(3)	(3)	(3)	80.66	122	Timer Stopped		80.57	119
12C	80.70	120	80.66	125	80.69	138	80.60	125	Timer Stopped		80.61	120
13C	80.69	119	80.61	125	80.61	130	80.56	122	Timer Stopped		80.61	117

1. Beat rate range for the timer redesign is 80.08 beats/second to 80.28 beats/second.
2. Timer numbers 11C, 12C, 13C are control units.
3. Test machine did not record data during these tests.

Table 7. Air gun test III

Unit #	g Level	Timer Function	Observations
1*	31811	Yes	Sleeve failure, loose dowel pin
2	30910	No	Sleeve failure, no. 1 plate failure, loose dowel pin
4	30552	No	No. 1 plate failure
5	30672	No	No. 1 plate failure, loose dowel pin
6	30298	No	Sleeve failure
7	30342	No	Sleeve failure, no. 1 plate failure, loose dowel pin
9	31434	Yes	Loose dowel pin
10	30488	Yes	
11	30788	No	Sleeve failure, loose dowel pin
12	29738	Yes	Sleeve failure, no. 1 plate failure
1**	30059	No	Hairspring broke, scroll shaft pushed-in
2	30193	No	#2 pinion pivot broke
4	29323	No	Hairspring broke
6	30127	Yes	
7	31333		
8	31254	Yes	
10	29292	Yes	
12	32051	No	#1 pinion damaged
13	27265	Yes	
15	30534	No	Hairspring broke

* Test units consisted of aluminum die cast no. 1 plates.
** Test units consisted of redesigned timer - die cast lower plate, external drive timing scroll movement, and escapement.
Tested: September 1981

Table 8. Air gun test IV

Unit #	g Level	Timer Function	Observations
1*	37240	No	No. 1 plate fracture, two dowel pins loose One screw stripped into no. 1 plate
2	29102	Yes	One dowel pin loose
3	30715	No	Two dowel pins loose, no. 1 plate fractured
4	30329	Yes	One dowel pin loose
5	28967	Yes	Two dowel pins loose
6	28967	Yes	Two dowel pins loose
7	29774	Yes	One dowel pin loose
8	30177	Yes	
9	29101	Yes	Two dowel pins loose
10	30043	Yes	Two dowel pins loose
11	29706	Yes	
12	35334	No	No. 1 plate fracture, two dowel pins worked loose

* Test units consisted of aluminum die cast no. 1 plate with counter bore removed and with .025 increased clearance with timer housing.

Tested: November 1981

Table 9. Air gun test V

Temp.: -40°F

Unit #	g Level	Timer Function	Observations
1*	22409	Yes	
2	23076	No	One dowel pin loose
3	25851	Yes	No. 1 plate fracture, one dowel pin loose
4	24938	No	One dowel pin loose
7	25489	Yes	One dowel pin loose
9	31382	No	One dowel pin loose
10	27165	No	One dowel pin loose
11	30725	No	Two dowel pins loose
12	25197	No	Two dowel pins loose
13	25004	No	One dowel pin loose
14**	22009	Yes	
15	23076	Yes	
16	25004	Yes	One dowel pin loose
17	25230	No	Two dowel pins loose
18	25585	No	One dowel pin loose, hub on lower plate broke
19	32085	No	Two dowel pins loose
20	29325	No	One dowel pin loose
21	29093	No	Two dowel pins loose
22	27294	Yes	Two dowel pins loose
25	27422	Yes	Two dowel pins loose

* Test units consisted of aluminum die cast no. 1 plate

** Test units consisted of aluminum die cast no. 1 plate, lower plate, external drive timing scroll movement, and escapement

Tested: February 1982

Table 10. Air gun test VI

Unit #	g Level	Timer Function	Observations
168	29,981	No	Loose dowel pin and screw, cracked no. 1 plate
166	27,582	No	Loose dowel pin and screw, cracked no. 1 plate
175*	27,630	Yes	Shaft moved in timing scroll
172	27,861	Yes	Loose screw
167	31,076	No	Balance wheel out of beat
169	30,169	No	Loose dowel pin, balance wheel out of beat
77	24,437	Yes	No visible damage
165	30,567	Yes	Balance wheel out of beat
122	30,434	No	Balance wheel out of beat
170	30,290	No	Loose dowel pin and screw; cracked no. 1 plate; balance wheel out of beat

* This unit was tested twice; the first time the g level was 18,646 g.

Tested: February 1984

Table 11. Ballistic test results using redesigned gear train and lower plate

TPR-LCN-T-2594, Supplement 5 — 24, 25, and 26 February 1982

Test Units - Lot No. HAT81G000E058

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
20	105mm, M103	7	50	145	20/20	50.066	.120
20	8 in., M2A2	1	25	-35	17/20	24.973	.055
20	155mm, M185	8	75	70	17/20	75.028 (outlier excluded)	.235
15	105mm, M204	8	75	70	15/15	75.272	.183
15	155mm, 198 System	8(M203)	105	70	15/15	105.291	.352
15	8 in., M10A2	9	105	70	15/15	105.253	.200

Control Units - Lot No. HAT82B000E078

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
20	105mm, M103	7	50	145	20/20	50.043	.068
20	8 in., M2A1	1	25	-35	17/20	24.946	.070
20	155mm, M185	8	75	70	20/20	75.064	.133
15	105mm, M204	8	75	70	13/15	75.193	.168
15	155mm, 198 System	8(M203)	105	70	15/15	104.969	.326
15	8 in., M10A2	9	105	70	15/15	105.091	.216

TPR-LCN-T-2672, Supplement 10 — 9 and 10 November 1982

Test Units - Lot No. HAT82K000E092

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
20	155mm, M185	8	75	70	20/20	74.923	.100
15	155mm, 198 System	8	105	70	15/15	104.872	.387
15	8 in., M10A2	9	100	70	15/15	100.008	.086

Control Units - Lot No. HAT82K000E093

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
20	155mm, M185	8	75	70	20/20	74.961	.172
15	155mm, 198 System	8	105	70	15/15	105.080	.329
15	8 in., M10A2	9	100	70	15/15	100.065	.092

Table 12. Ballistic test results using die cast no. 1 plate

TPR-LCN-T-2594, Supplement 4 — 3 and 4 May 1982

Test Units - Lot No. HAT82D000E057

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
15	105mm, M204	8	75	70	15/15	75.153	.116
20	105mm, M103	7	50	145	20/20	50.115	.068
Control Units - Lot No. HAT82D000E088							
15	105mm, M204	8	75	70	15/15	75.160	.144
20	105mm, M103	7	50	145	20/20	50.130	.091

Table 13. Ballistic test results with combination units

TPR-LCN-T-2672, Supplement 14
Test Units - Lot No. HAT82M000E060

# of Units	Gun	Zone	Time Sec.	Environment (°F)	Function	Mean	Std. Dev.
(1)10	(FFE) 155mm, M198 System	8	75	70	10/10	75.115	.077
10	(SR) 155mm, M198 System	8	75	70	10/10	74.979	.067
(2)15	155mm, M185, M119 CH6	8	75	70	14/15	74.970	.148
(3)15	155mm, M198 System M203 CH6	8	100	70	14/15	100.114	.282
15	105mm, M103	7	50	145	14/15	50.135	.096
(4)10	155mm, M198 System RAP Round	8	95	70	10/10	95.148	.165
Control Units - Lot No. HAT82M000E096							
(5)10	(FFE) 155mm, M198 System	8	75	70	10/10	75.042	.074
10	(SR) 155mm, M198 System	8	75	70	10/10	74.964	.135
15	155mm, M185, M119 CH6	8	75	70	15/15	74.999	.094
15	155mm, M198 System, M203 CH6	8	100	70	15/15	100.066	.266
15	105mm, M103	7	50	145	14/15	50.056	.051
(6)10	155mm, M198 System RAP Round	8	95	70	10/10	95.076	.095

(1) Chronographs failed to record time on 6 of the 10 units tested.
(2) One fuze time was lost on chronographs.
(3) One fuze time was lost on chronographs. One fuze was an outlier and one fuze was a dud. The mean and std. deviation were calculated from a sample of 12 units.
(4) Three rounds were lost on the chronographs; the units were listed by H. Eades as no-tests.
(5) Chronographs failed to record time on 6 of the 10 units tested.
(6) Two rounds were lost on the chronographs; the units were listed by H. Eades as no-tests.

COST AND WEIGHT

Cost Comparison

The total projected cost savings is $1.05 per fuze. This cost savings was calculated using a quantity of 500,000 units and the lowest price obtained from vendors for purchased parts. This cost savings includes material, labor, overhead, and general and administrative costs but do not include tools, gages, and profit. The estimated cost of production tools and gages is $343,832. This includes multiple sets of tools where needed to maintain a production level of 500,000 units per year. A cost comparison of the present design and new design is shown in Table 4. Parts which are common to the present and new design are not included in the analysis.

A previous cost projection showed a savings of $1.76 per fuze without general and administrative costs. This savings significantly changed for the following reasons:

1. The cost of the redesigned scroll increased by $.45.
2. The cost of the present no. 1 plate decreased by $.37.
3. The cost of the lower plate increased by $.14.

Weight Comparison

A weight comparison of the changed parts and subassemblies is given in Table 15. The net change to the fuze is .003 pounds decrease, which is insignificant.

Table 14. Cost Comparison per fuze

Part or Assembly Name	Present Design	Proposed Design	Savings	Tools & Gages
Plate #3	0.07	0.07	0.00	32604.00
Plate #4	0.11	0.12	-0.01	29969.00
Pinion #2	0.11	0.11	0.00	9104.00
Drive Gear	0.15	0.18	-0.04	13273.00
Ring Gear Shaft	0.34	0.06	0.28	0.00
Ring Gear Support	0.24	0.00	0.24	0.00
Ring Gear Support Assy.	0.08	0.00	0.08	0.00
Support & Shaft Assy.	0.25	0.00	0.25	0.00
Scroll	0.52	1.07	-0.55	44498.00
Scroll Assy.	0.09	0.11	-0.02	11257.00
Plate #6	0.79	0.00	0.79	0.00
Plate #5	0.07	0.00	0.07	0.00
Lower Plate	0.00	0.65	-0.65	35873.00
Plate #1	0.99	0.54	0.45	39366.00
Setting Ring Gear	0.15	0.22	-0.06	45515.00
Setting Ring Gear Assy.	0.10	0.00	0.10	0.00
Ring Gear Dowel Pin	0.01	0.00	0.01	0.00
Dowel Pin	0.03	0.03	0.00	493.00
Plate #1 Assy.	0.28	0.32	-0.04	3861.00
Timer Assy.	2.51	2.48	0.03	6675.00
Spacer (Ctr. Assy.)	0.02	0.02	0.00	125.00
Sleeve	1.68	1.68	0.00	1623.00
.025 Spacer	0.00	0.04	-0.04	0.00
Lever Assy.				35050.00
Escape Wheel Assy.				2305.00
Gear #1				12444.00
Gear #2				15187.00
Gear #2 Assy.				2305.00
Gear #1 Assy.				2305.00
Total			0.88	343832.00
G&A			0.17	

Table 15. Weight comparison

	Present	Proposed	Net Change
Scroll Assembly	.0855	.0811	(.0044)
No. 1 Plate Assembly	.0306	.0304	(.0002)
Lower Plate versus No. 5 and No. 6 Plate	.0136	.0145	.0009
Gear Train	.0009	.0015	.0006

CONCLUSIONS AND RECOMMENDATIONS

The timer redesign, including the aluminum die cast no. 1 plate, external drive gear with redesigned gear train, and aluminum die cast lower plate, was subjected to the required laboratory and ballistic tests with acceptable results. Based on test results and a projected cost savings of $1.05 per fuze, this design has been shown to be a feasible replacement for the present timer. However, because of the large number of parts and subassemblies involved in the timer redesign and the fact that development tests were conducted on units fabricated mainly from development tooling and because the timer is the most important safety and functional component of the fuze, HTI strongly recommends that additional ballistic tests be conducted using production tooling and the inertial PD VECP design prior to releasing the design to production. Using the timer redesign with the M577A1 fuze, the inertial PD design, requires that the sleeve, setting key, and ogive be changed. In consideration of the nature and significance of the change to the timer assembly and since the timer change was not tested with the M577A1 fuze, it would be to the mutual benefit of all to perform additional testing on an increased sample produced from production tooling.

APPENDIX A
CALCULATION OF LOAD ON NO. 1 PLATE

The no. 1 plate is loaded during setback when the timer housing deforms enough to hit the no. 1 plate. The load of the setting mechanism, counter assembly, and timer housing assembly less cylindrical portion is transmitted to the no. 1 plate through the timer housing. The load from the cylindrical portion of the timer housing is transferred to the tumblers, not the no. 1 plate. Table 10 shows the weights necessary to calculate the load on the no. 1 plate.

At 30,000g acceleration, the load on the top of the timer housing is

$$F = wg$$

$$= (.1228 \text{ lb.})\ (30{,}000g)$$

$$= 3684 \text{ lb.}$$

The minimum clearance during setback without deformation of the timer housing in the well area of the no. 1 plate and the timer housing assembly is .013 inch. Therefore, the timer housing must deform .013 inch before the timer housing assembly hits the no. 1 plate. Laboratory static tests showed the timer housing deflects .001 inch for every 34.3 lb. of loading. Therefore, the load absorbed by the timer housing is

$$\text{Load} = (.013)\ (34.3)\ (1000)$$

$$= 446 \text{ lbs.}$$

Hence the net load on the no. 1 plate at 30,000g is 3238 lb.

Table A-1. Weight of assemblies used in load calculations

Assembly	Part No.	Weight (lbs.)
Setting Mechanism	See Note	0.0315
Counter Assembly	9236573	.0578
Timer Housing Assy.	9236588	.0758
Cylindrical Portion		.0423

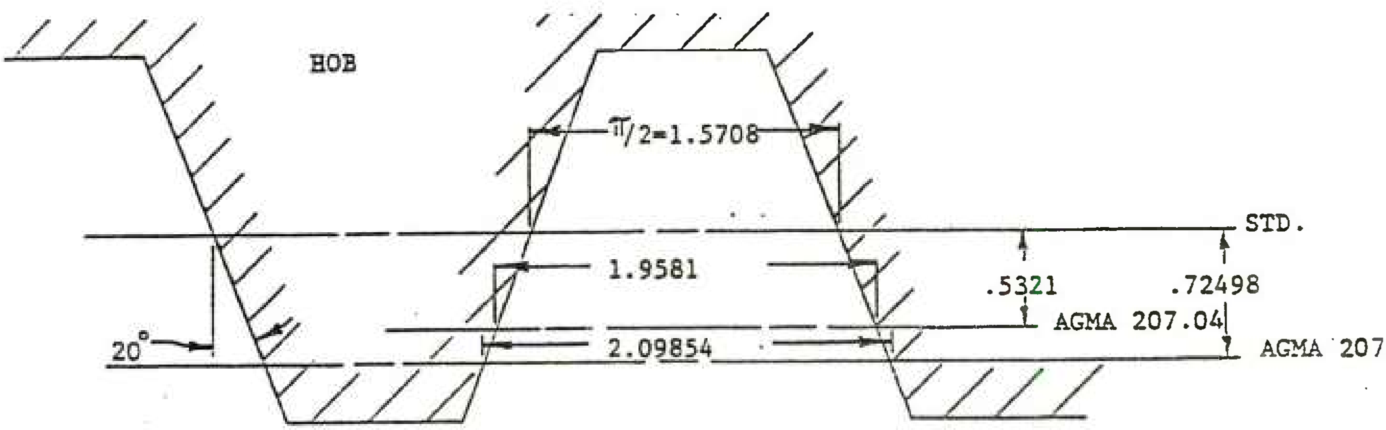
Note: Setting mechanism includes setting key ring (9236515), setting key (9236517), crush tube (9236730), retainer plug (9236731), clutch drive sleeve (9236520), nine clutch grip rings (9236570), three clutch spacers (9236571), set clutch washer (9236551), and spacer (9236566).

APPENDIX B

ANALYSIS OF THE DESIGN USED ON DRIVE GEAR AND NO. 2 PINION

The present timer redesign requires the use of an 8 tooth, 72 DP pinion meshing with a 43 tooth gear using the 20° involute system. Because of the low numbered pinion required, tooth form modification is necessary to provide sufficient contact ratio and tooth strength. The following is a comparison of the strength and operating characteristics obtainable using AGMA recommended modifications. Both the "enlarged center distance" and the "long and short addendum" systems of both AGMA standard 207.04 and 207.06 are compared.

Both of the above standards use conventional hob withdrawal techniques to achieve a "long addendum" pinion which is then paired with either a "short addendum" gear on standard centers or a standard addendum gear on "enlarged centers." They differ only in the amount of hob withdrawal recommended and O.D. modification to prevent pointed teeth.



For 8 tooth pinions, DP = 1	AGMA 207.04	207.06
Basic tooth thickness (t_p)	1.9581	2.09854
Hob shift required (Δ)	.5321	.72498
$\Delta = (t_p - \pi/2)/2 \text{ Tan } 20^\circ$		
O.D.	10.8738	11.0250

The maximum limits of involute contact for any gear or pinion with respect to its generated pitch point may be calculated from a knowledge of the following four radii.

R_p = pitch radius = $N/(2\ DP)$

R_o = outside radius = $\dfrac{(\frac{N}{2} + 1)}{DP}$

R_b = base radius = R_p Cos

R_t = transition radius (or inside form radius)

this radius represents the point of intersection or tangency of the involute curve and the trochoidal fillet or undercut.

The following analysis for determining R_t is derived from Buckingham's "Analytical Mechanics of Gears" p. 58, 74 and 80.

The relative strengths of the various gear and pinion geometries were compared by calculating the "Y" factor for each design in accordance with the procedure described in AGMA standard 220.02, Appendix A. The bending stress is considered to be inversely proportional to "Y." Thus, tooth strength is directly proportional to "Y."

Tabulation of the parameters relating to the three gears and two pinions studied is shown in Table B-1. The parameters related to the four gear and pinion combinations derived from the gear and pinion components are shown in Table B-2.

Table B-1

Component Data

	Long Add. AGMA 207.04	Short Add AGMA 207.04	Long Add AGMA 207.06	Short Add. AGMA 207.06	Standard
a_o	20^o	20^o	20^o	20^o	20^o
N	8	43	8	43	43
t_p	1.9581	1.1835	2.09854	1.04305	1.5708
	+.5321	-.5321	+.72498	-.72498	0
b	.8119	1.8761	.61902	2.06898	1.3440
R_o	5.4369	21.9679	5.51250	21.77500	22.5000
R_p	4.0000	21.5000	4.00000	21.50000	21.5000
R_t	3.7813	20.2896	3.76404	20.24544	20.4914
R_b	3.7588	20.2034	3.75877	20.20339	20.2034
A	2.5603	1.2728	2.6643	.7690	2.5498
B	.9559	5.4853	1.1691	6.0494	3.9296
"Y"	.401	.318	.508	.285	.413

Table B-2

Gear/Pinion Combination Data

	AGMA 207.04		AGMA 207.06	
	Long & Short Add System	Enlarged Centers System	Long & Short System	Enlarged Centers System
a	20°	22.824°	20°	23.678°
CD	25.0000	25.9978	25.5000	26.1648
R_p (pinion)	4.0000	4.0782	4.0000	4.1043
R_p (gear)	21.5000	21.9205	21.5000	22.0605
A (pinion)	2.5603	2.3461	2.6643	2.3840
B (gear)	5.4853	5.0813	6.0494	5.4359
A (gear)	1.2728	1.3984	.7690	1.0438
B (pinion)	.9559	1.1701	1.1691	1.4492
L	3.5162	3.5162	3.4333	3.4278
CR	1.191	1.191	1.163	1.161
X	.8810	.7924	.4812	.4757
CD	.3146	.3175	.1686	.1946
a_o'	21.838°	24.414°	21.009°	24.625°
Y min of pair	.318	.401	.285	.413

(Data at <u>operating</u> pressure angle)

(All dimensions based on DP = 1)

The design selected for this application was the "long addendum" pinion of AGMA 207.04 used in combination with a standard gear on enlarged centers.

This combination was selected because it affords the greatest center distance separation tolerance (.3175/72 = .0044") together with a strength factor within 3% of the maximum obtainable.

<u>Stress Analysis of Drive Gear</u>

The tooth strength of the involute drive gear was studied and compared to the present design. Two methods were used to calculate the bending stress on a tooth.

The transmitted tangential load at the pitch diameter is calculated by

$$W_t = \text{torque/pitch radius}$$

$$= (34 \text{ in.-oz./16 oz./lb.}) \left(\frac{2}{.5972 \text{ in.}} \right)$$

$$= 7.117 \text{ lb.}$$

According to AGMA 220.02, the tensile bending stress, S_t, at the root of the tooth is calculated by

$$S_t = \left(\frac{W_t \, K_o}{K_r} \right) \left(\frac{P}{F} \right) \left(\frac{K_s \, K_m}{J} \right),$$

where

W_t	= 7.117 lb.	transmitted tangential load
K_o	= 1	overload factor
K_v	= 1	dynamic factor
P	= 72	diametral pitch
F	= .040 in.	face width
K_s	= 1	size factor
K_m	= 1.3	load distribution factor
J	= .275	geometry factor

The value of the factors used in the formula are obtained from tables or graphs in AGMA 220.02. Using a tangential load of 7.117 lb., a diametral pitch of 72, and a face width of .040 in., we have

$$S_t = \frac{(7.117)(1)}{1} \quad \frac{72}{.040} \quad \frac{(1)(1.3)}{.275}$$

$$= 60{,}559 \text{ psi.}$$

Using the Lewis formula, the maximum bending stress, S_t, is calculated by

$$S = \frac{W_t K P}{F Y},$$

where

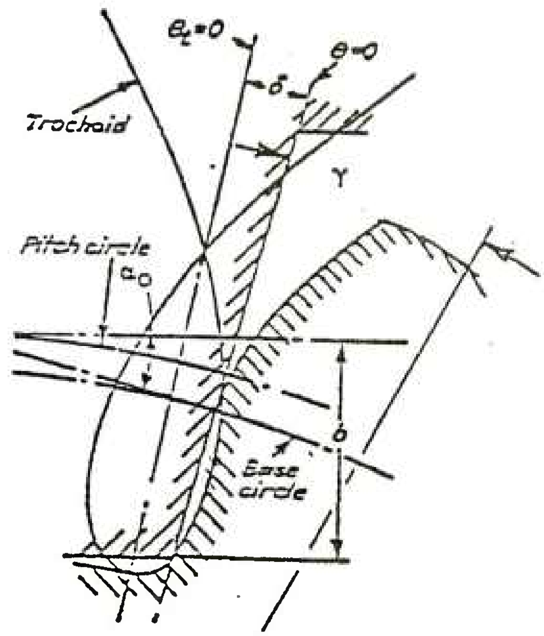
W_t	= 7.117 lb.	transmitted tangential load
K	= 1.5	stress concentration factor
P	= 72	diametral pitch
F	= .04 in.	face width
Y	= .413	form factor

The value of K is the common value used for 20-degree pressure angle gears; the form factor, Y, is calculated in the previous section of this appendix. With these values, we obtain

$$S_t = \frac{(7.117)(1.5)(72)}{(.04)(.413)}$$

$$= 46{,}528 \text{ psi.}$$

Using the larger of the two estimates, we assume a stress of 60,559 psi. To provide protection against overloading caused by overwinding, this figure is doubled. A design value of 121,000 psi. for bending tooth stress is well below the published yield strength of 140,000 psi. for beryllium copper with a hardness of Rc37.



θ_t = vectorial angle of trochoid

δ = angle between origins of trochoid and involute

θ = vectorial angle of involute

θ_c = vectorial angle from tooth centerline

b = hob addendum

α_o = generating pressure angle

γ = angle between origin of involute and centerline

R_p = pitch radius

R_b = base radius

T_p = tooth thickness at pitch radius

$$\theta_t = \tan^{-1} \sqrt{\frac{R^2-(R_p-b)^2}{R_p-b}} - \sqrt{\frac{R^2-(R_p-b)^2}{R_p}}$$

$$\delta = \alpha_o - \frac{(R_p-b)}{R_p} \tan \alpha_o$$ (∡ from ℄ of trochoid to start of inv. at base radius)

$$\theta = \sqrt{\frac{R^2-R_b^2}{R_b}} - \tan^{-1} \sqrt{\frac{R^2-R_b^2}{R_b}}$$

$$\gamma = \frac{T_p}{2R_p} + \text{inv } \alpha_o$$ (∡ from start of inv. at base radius to ℄ of tooth)

$\theta_c = \gamma - \theta$ for involute portion

$\theta_c = \gamma + \delta - \theta_t$ for trochoidal portion

θ_c (involute) $= \gamma - \theta = \gamma + \delta - \theta_t = \theta_c$ (trochoid)

Transition occurs when $\theta = \theta_t - \delta$

R at transition $= R_t$

$$\theta - \theta_t + \delta = 0$$

$$\sqrt{\frac{R^2-R_b^2}{R_b}} - \tan^{-1} \sqrt{\frac{R^2-R_b^2}{R_b}} - \tan^{-1} \sqrt{\frac{R^2-(R_p-b)^2}{R_p-b}} + \sqrt{\frac{R^2-(R_p-b)^2}{R_p}}$$

$$+ \alpha_o - \frac{(R_p-b)}{R_p} \tan \alpha_o = 0$$

the value of R satisfying this equation equals R_t

For the following computations a sharp edged hob is assumed with an addendum b equal to 1.200/DP + .002" which for the present case of 72 DP scaled to DP = 1 gives b = 1.344.

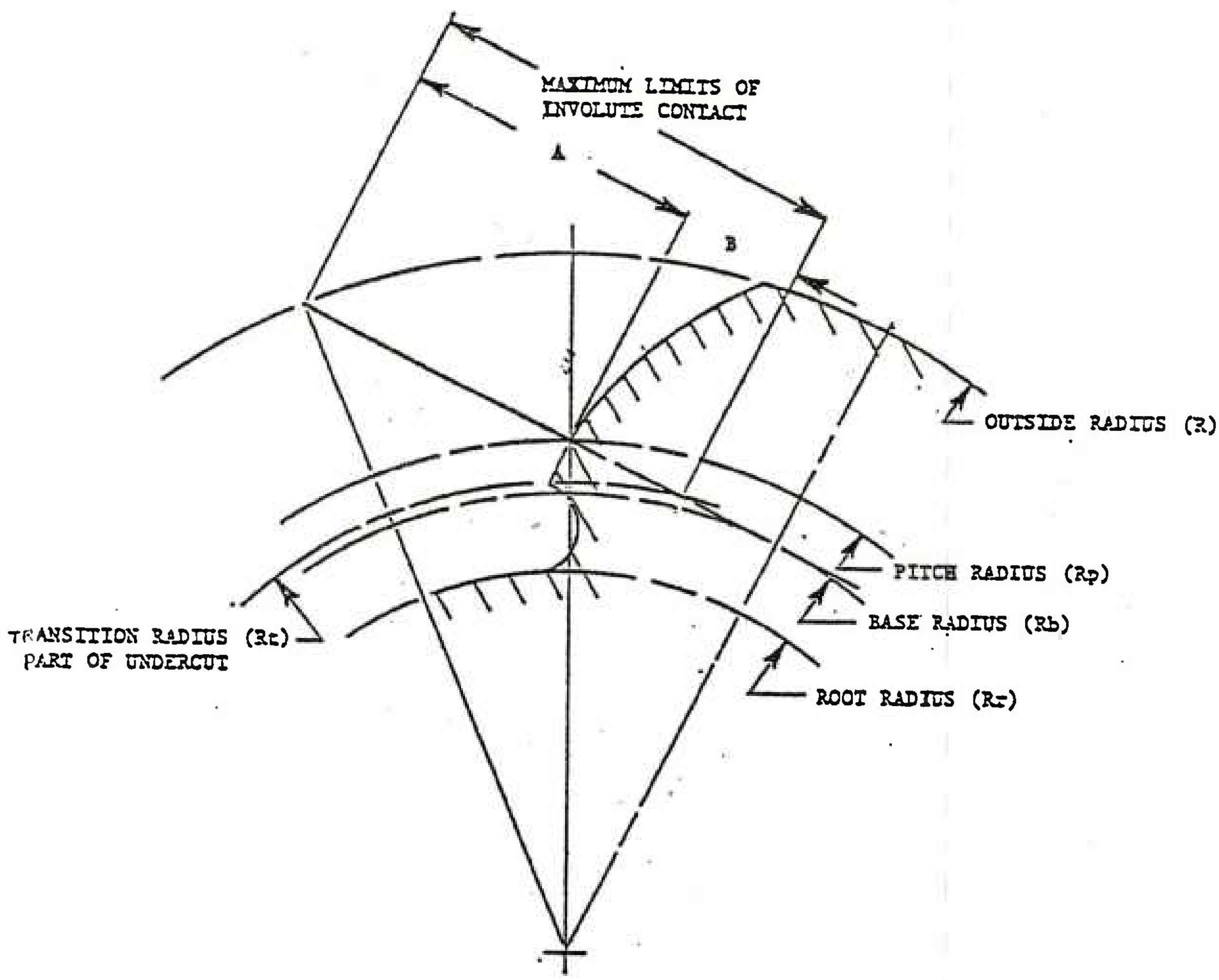
	N = 8 Long Add. 207.04	N = 43 Short Add. 207.04	N = 8 Long Add. 207.06	N = 43 Short Add. 207.06	N = 43 STD
α_o = generating pressure ∢	20°	20°	20°	20°	20°
Δ = hob offset	+.5321	−.5321	+.72498	−.72498	0
$b = 1.344 - \Delta$	.8119	1.8761	.61902	2.06898	1.3440
$R_p = N/2$	4.0000	21.5000	4.0000	21.5000	21.5000
$R_b = (N/2)\cos\alpha$	3.7588	20.2034	3.7588	20.2034	20.2034
R_o =	5.4369	21.9679	5.5125	21.7750	22.5000
R_t =	3.78132	20.28958	3.76406	20.24544	20.49145

Using the above four radii the involute path lengths A & B shown on the following sketch can be computed from the following considerations.

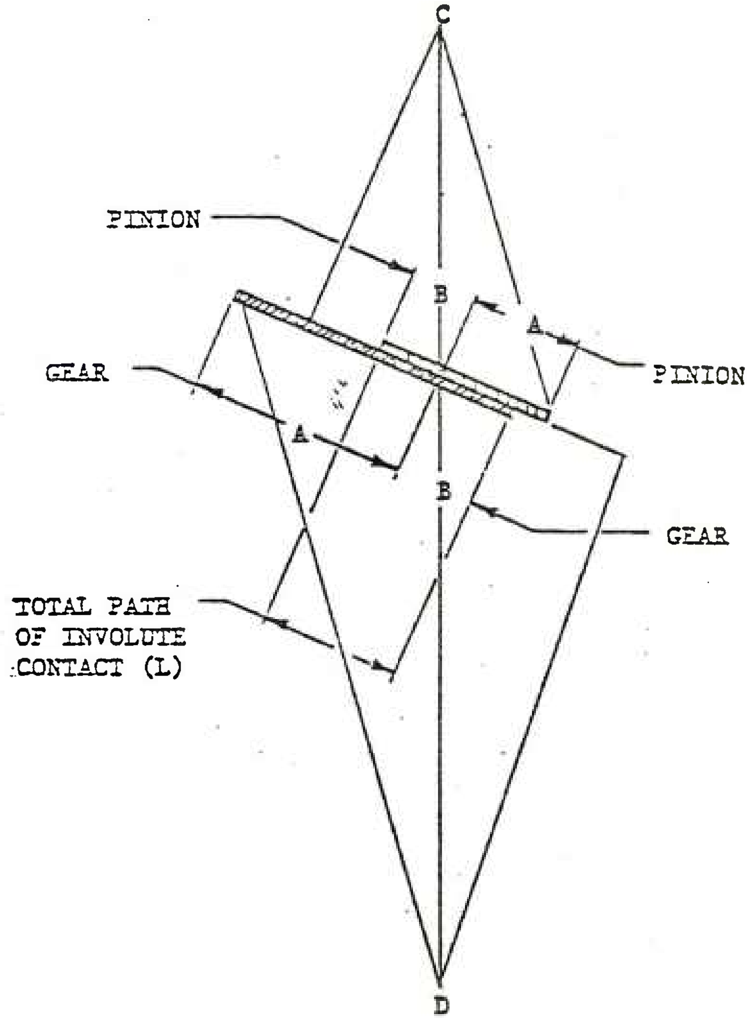
$$A = \sqrt{R_o^2 - R_b^2} - \sqrt{R_p^2 - R_b^2}$$

$$B = \sqrt{R_p^2 - R_b^2} - \sqrt{R_t^2 - R_b^2}$$

A	2.5603	1.2728	2.6643	.7690	2.5498
B	.9559	5.4853	1.1691	6.0494	3.9296
A + B	3.5162	6.7581	3.8333	6.8184	6.4794


MAXIMUM LIMITS OF
INVOLUTE CONTACT
A
B
OUTSIDE RADIUS (R)
PITCH RADIUS (Rp)
BASE RADIUS (Rb)
TRANSITION RADIUS (Rt)
PART OF UNDERCUT
ROOT RADIUS (Rr)

When either "long and short addendum" pair is tightly meshed on standard centers the pinion path A overlaps the gear path B and vice versa. The resulting contact path is the sum of the lesser of each overlapping pair as shown.



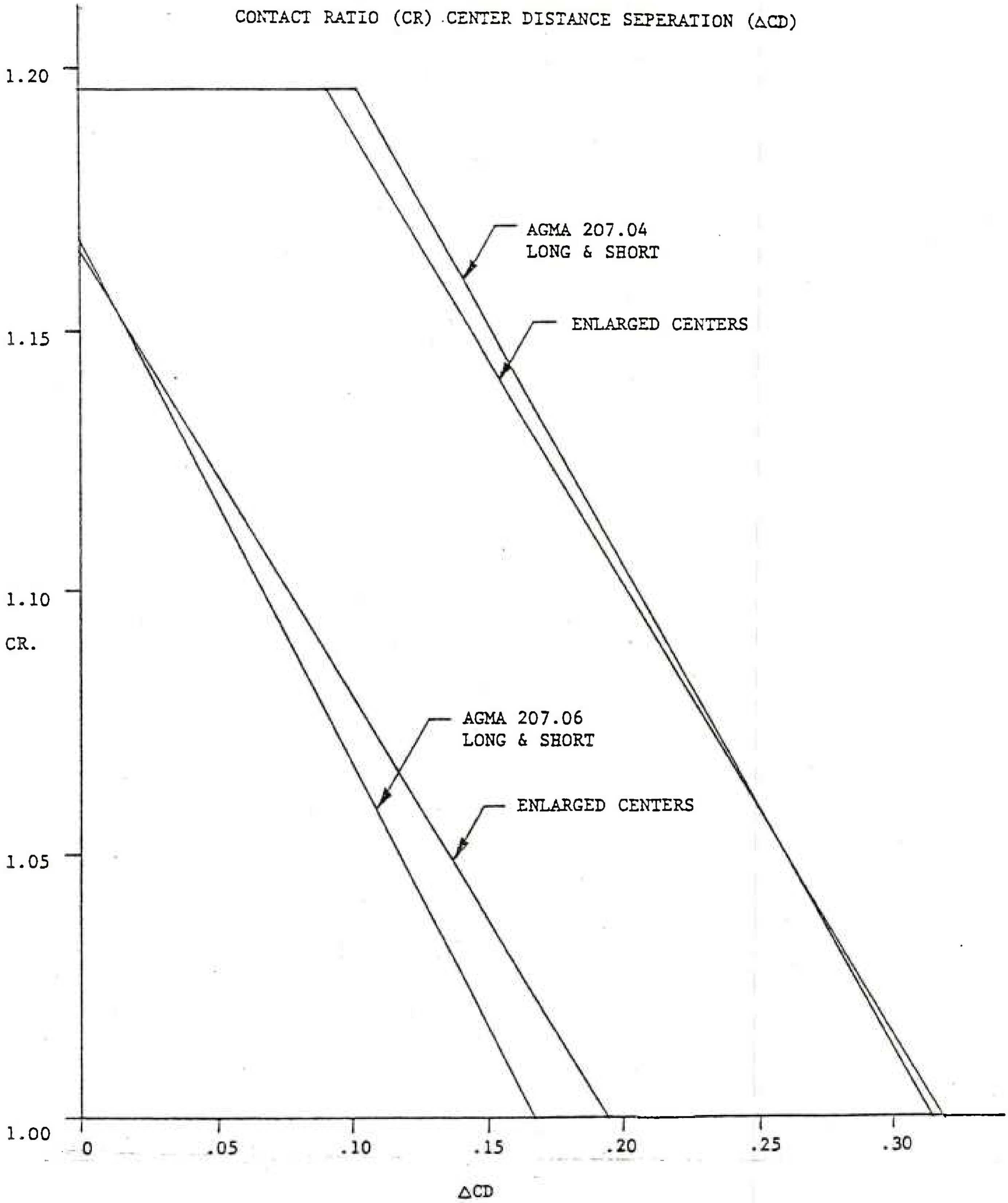
For 207.04 L = Lesser of $\begin{matrix}1.2728\\.9559\end{matrix}$ + lesser of $\begin{matrix}2.5603\\5.4853\end{matrix}$ = 3.5162

For 207.06 L = Lesser of $\begin{matrix}.7690\\1.1691\end{matrix}$ + lessor of $\begin{matrix}2.6643\\6.0494\end{matrix}$ = 3.4333

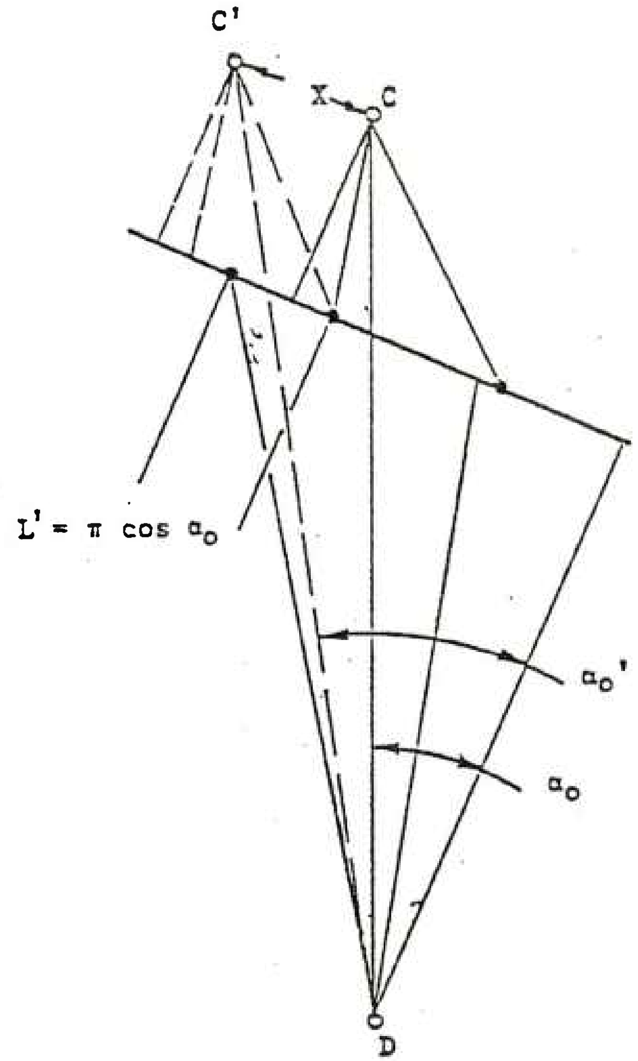
Dividing this length (L) by the base pitch ($\pi \cos \alpha$) gives the contact ratio (CR) for each set.

CR = 1.191 for 207.04

= 1.163 for 207.06


CONTACT RATIO (CR) CENTER DISTANCE SEPERATION (ΔCD)
1.20
1.15
1.10
CR.
1.05
1.00
0
.05
.10
.15
.20
.25
.30
ΔCD
AGMA 207.04
LONG & SHORT
ENLARGED CENTERS
AGMA 207.06
LONG & SHORT
ENLARGED CENTERS

If the pinion center (C) is translated a dist X parallel to L until $L' = \pi \cos \alpha_o$ (CR = 1) the distance C'D equals the maximum center distance for full involute action. The operating pressure angle at this center distance is α'_o



$$X = A\ \text{gear} + A\ \text{pinion} - \pi \cos \alpha_o$$

$$\overline{C'D} = \sqrt{(\overline{CD} + X \sin \alpha_o)^2 + X \cos \alpha_o{}^2}$$

$$\Delta_{CD} = \overline{C'D} - \overline{CD}$$

$$\alpha_o' = \text{Tan}^{-1} \frac{X + \overline{CD} \sin \alpha_o}{\overline{CD} \cos \alpha_o}$$

To evaluate the "enlarged center distance" system the following additional computations are required to determine the operating pressure angle (α_1), the center distance at tightest mesh ($\overline{CD}_1$) and the operating pitch radii (Rp_1).

$$\alpha_1 = \text{inv}^{-1} \left(\text{inv } \alpha_o + \frac{t_G + t_p - \pi}{N_G + N_p} \right)$$

Buckingham "Analytical Mechanics of Gears", P. 96

$$\overline{CD}_1 = \frac{N_G + N_p}{2} \quad \frac{\cos \alpha_o}{\cos \alpha_1}$$

$$Rp_1 \text{ (gear)} = \frac{N_G}{N_G + N_p} \quad (\overline{CD}_1)$$

$$Rp_1 \text{ (pinion)} = \frac{N_p}{N_G + N_p} \quad (\overline{CD}_1)$$

where α_o = generating pressure angle

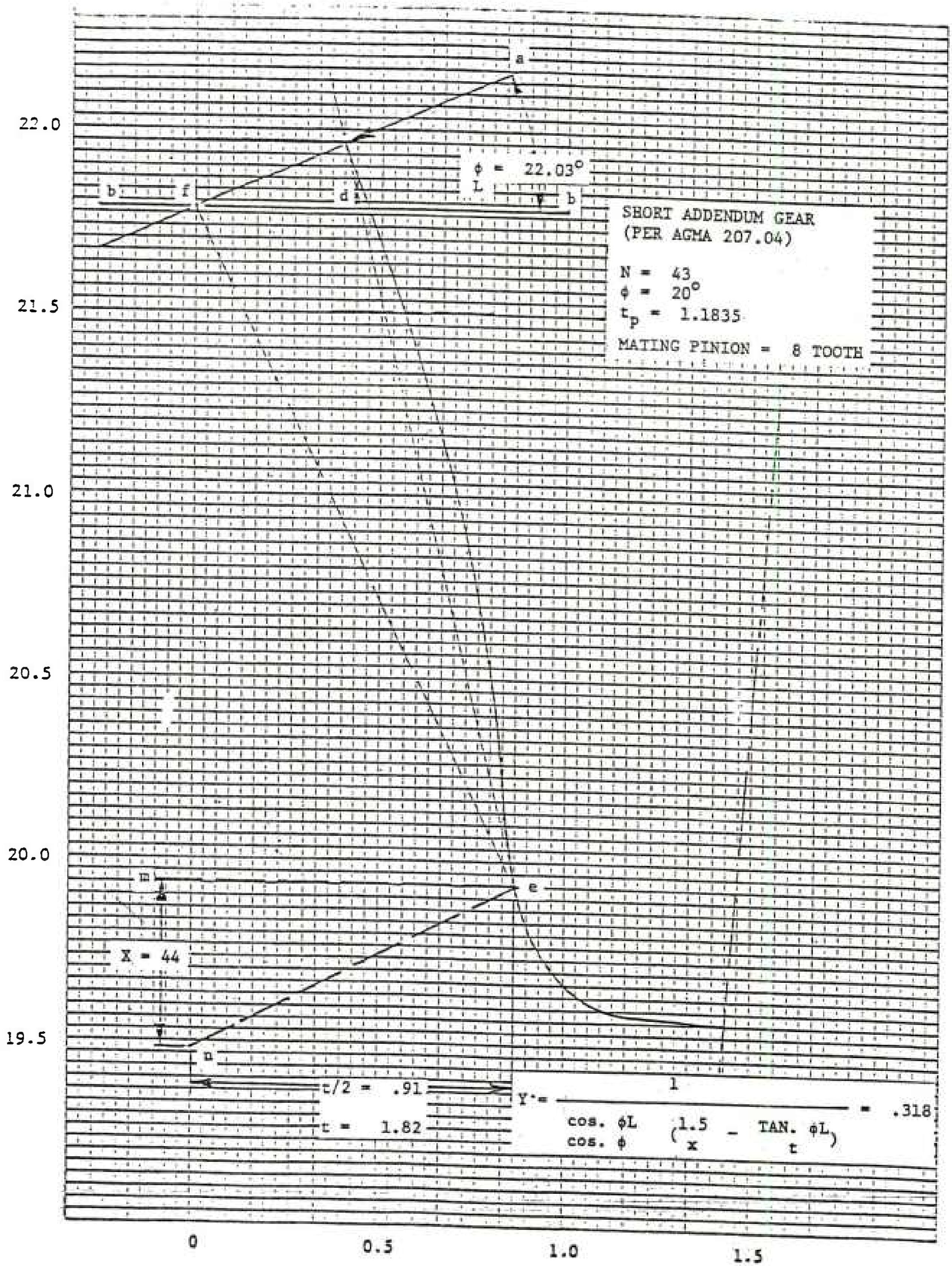
t_p = arc thickness of pinion at the generating pressure angle α_o

t_G = arc thickness of gear at the generating pressure angle α_o

N_G = No. of gear teeth

N_p = No. of pinion teeth

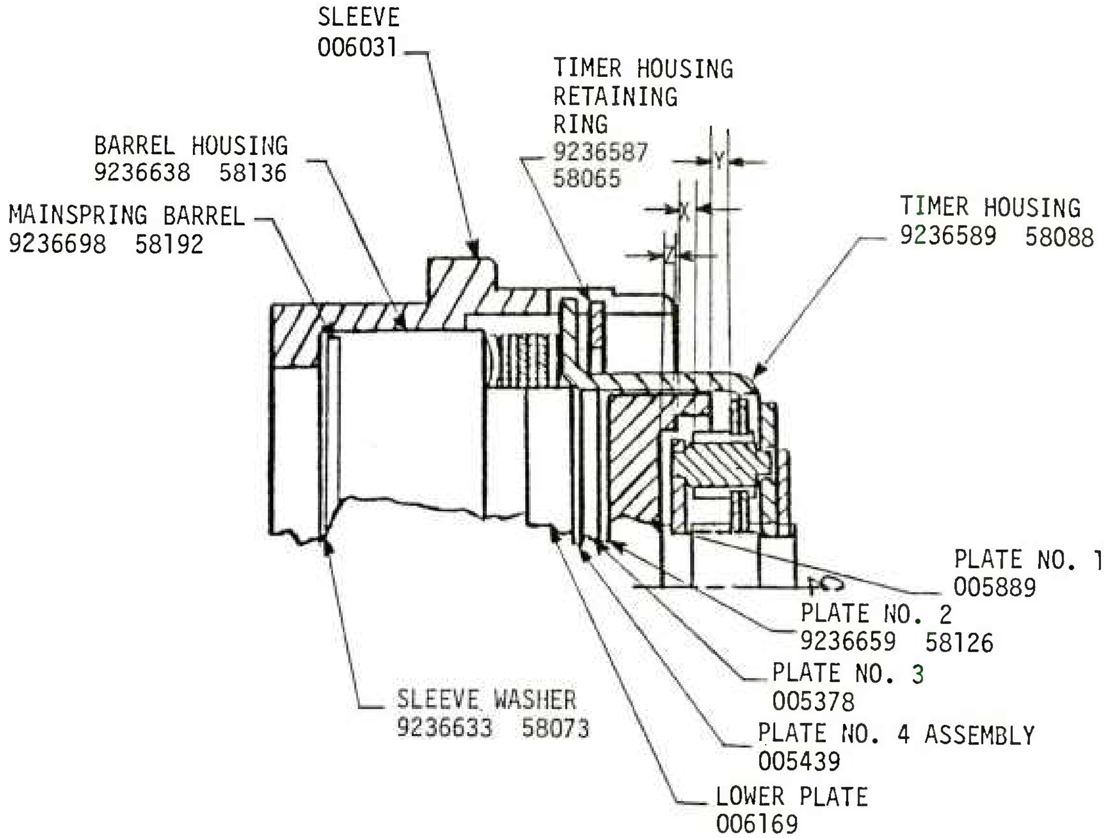
The values of A, B, L, X, Δ_{CD} and α_o' can now be calculated as before.



SHORT ADDENDUM GEAR
(PER AGMA 207.04)
N = 43
φ = 20°
t_p = 1.1835
MATING PINION = 8 TOOTH
φ = 22.03°
L
a
b
f
d
b
e
m
n
X = 44
t/2 = .91
t = 1.82
$Y' = \dfrac{1}{\dfrac{\cos \phi L}{\cos \phi}\left(\dfrac{1.5}{x} - \dfrac{\tan \phi L}{t}\right)} = .318$
22.0
21.5
21.0
20.5
20.0
19.5
0
0.5
1.0
1.5

APPENDIX C
TOLERANCE STUDIES

TOLERANCE STUDIES FOR PIP DESIGNED PLATE
NO. 1

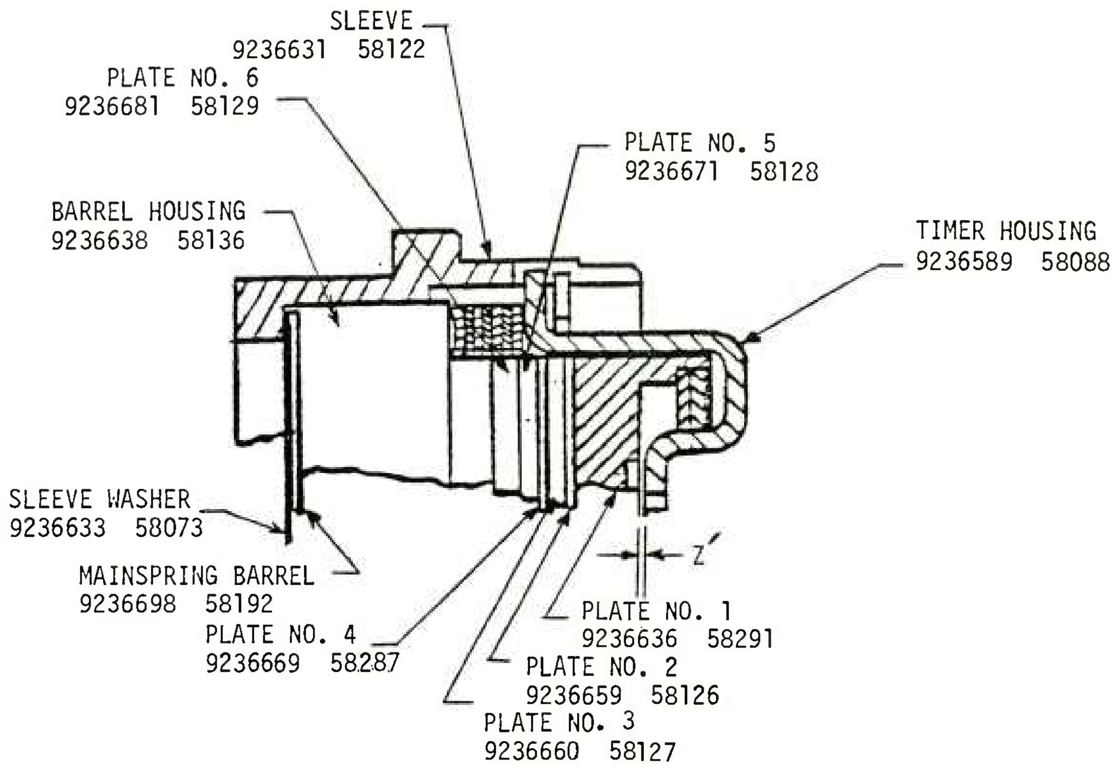


Tolerance study to determine the clearance between the setting pinion and shelf of the PIP designed plate no. 1 when assembled (shown as dimension X).

		+	-
Plate #1	(-) .236	-.005	
Plate #2	(-) .025	-.001	+.001
Plate #3	(-) .052	-.002	
Plate #4	(-) .0225	-.0035	
Lower Plate	(-) .136	-.002	+.002
Barrel Housing	(-) .562	-.003	
Mainspring Barrel	(-) .027	-.004	
Mainspring Barrel	(-) .006	-.002	+.002
Sleeve Washer	(-) .012	-.0015	
Sleeve	.805		-.004
Retainer Ring	(-) .035	-.002	.002
Timer Housing	(-) .056	-.006	
Timer Housing	.622		-.005
Timer Housing	(-) .225		+.005
Setting Pinion	.026	+.003	

X = .0585 +.035 -.021
X = .0375/.0935

TOLERANCE STUDIES FOR THE PRESENT NO. 1 PLATE



Tolerance study that determines the clearance between the counterbore of the present Plate #1 and the Timer Housing. (Shown as Dimension Z'.)

		+	-
Plate #1	(-) .183	-.005	
Plate #2	(-) .025	-.001	+.001
Plate #3	(-) .052	-.002	
Plate #4	(-) .0225	-.0035	
Plate #5	(-) .071	-.001	+.001
Plate #6	(-) .066	-.002	
Barrel Housing	(-) .562	-.003	
Mainspring Barrel	(-) .027	-.004	
Mainspring Barrel	(-) .006	-.002	+.002
Sleeve Washer	(-) .012	-.0015	
Sleeve	.780		-.004
Retainer Ring	(-) .035	-.002	+.002
Timer Housing	(-) .056	-.006	
Timer Housing	.622		-.005
Timer Housing	(-) .225		+.005
Timer Housing	(-) .052	-.010	

Z' = .0075 +.043 -.020
Z' = .0505/-.0125

Tolerance study to determine the clearance between the Timer Housing and the well area of the PIP designed Plate #1. (Shown as Dimension Z.)

		+	-
Plate #1	(-) .158	-.005	
Plate #2	(-) .025	-.001	+.001
Plate #3	(-) .052	-.002	
Plate #4	(-) .0225	-.0035	
Lower Plate	(-) .136	-.002	+.002
Barrel Housing	(-) .562	-.003	
Mainspring Barrel	(-) .027	-.004	
Mainspring Barrel	(-) .006	-.002	+.002
Sleeve Washer	(-) .012	-.0015	
Sleeve	.805		-.004
Retainer Ring	(-) .035	-.002	+.002
Timer Housing	(-) .056	-.006	
Timer Housing	.622		-.005
Timer Housing	(-) .225		+.005
Timer Housing	(-) .052	-.010	

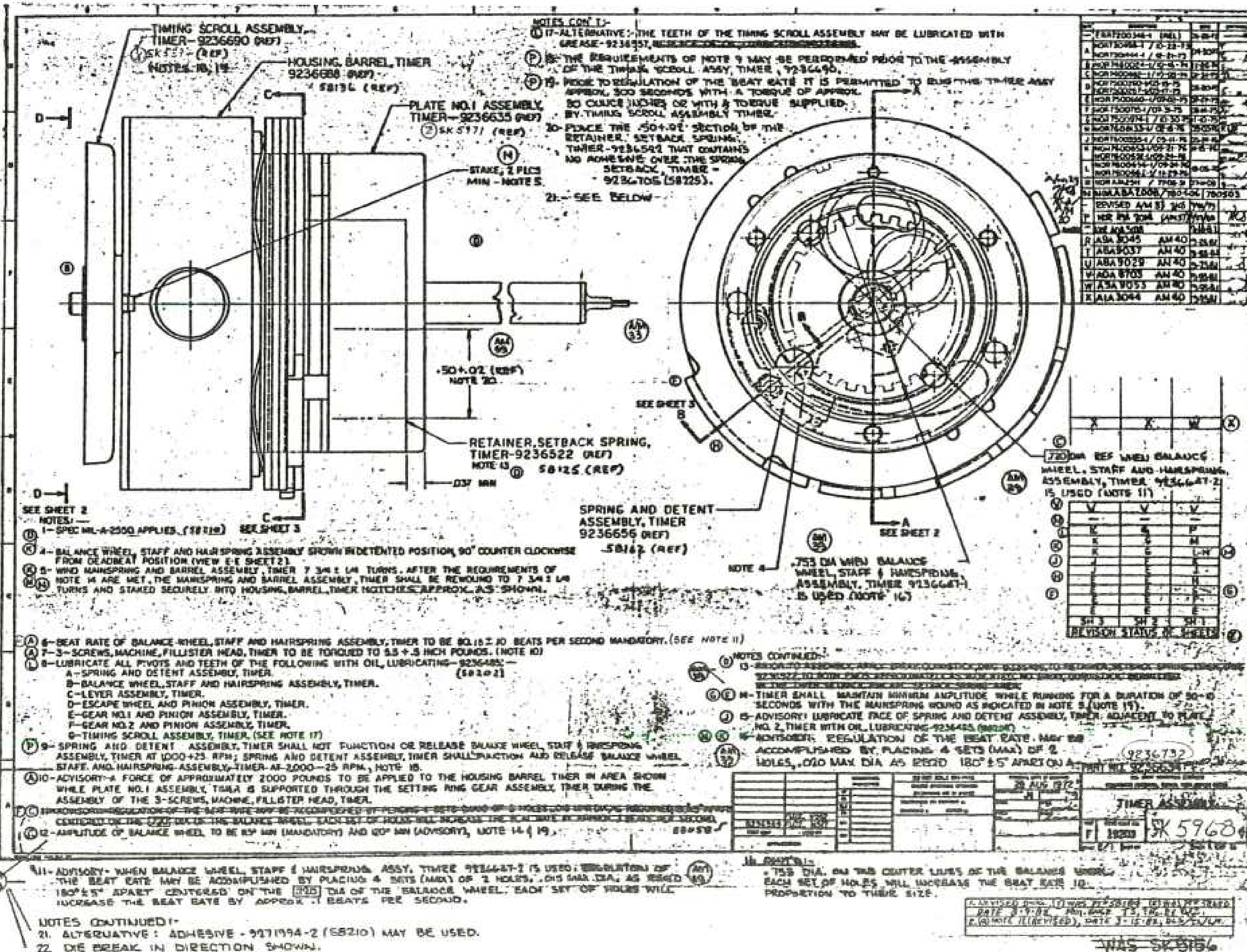
Z = .0585 +.042 -.021
Z = .1005/.0375

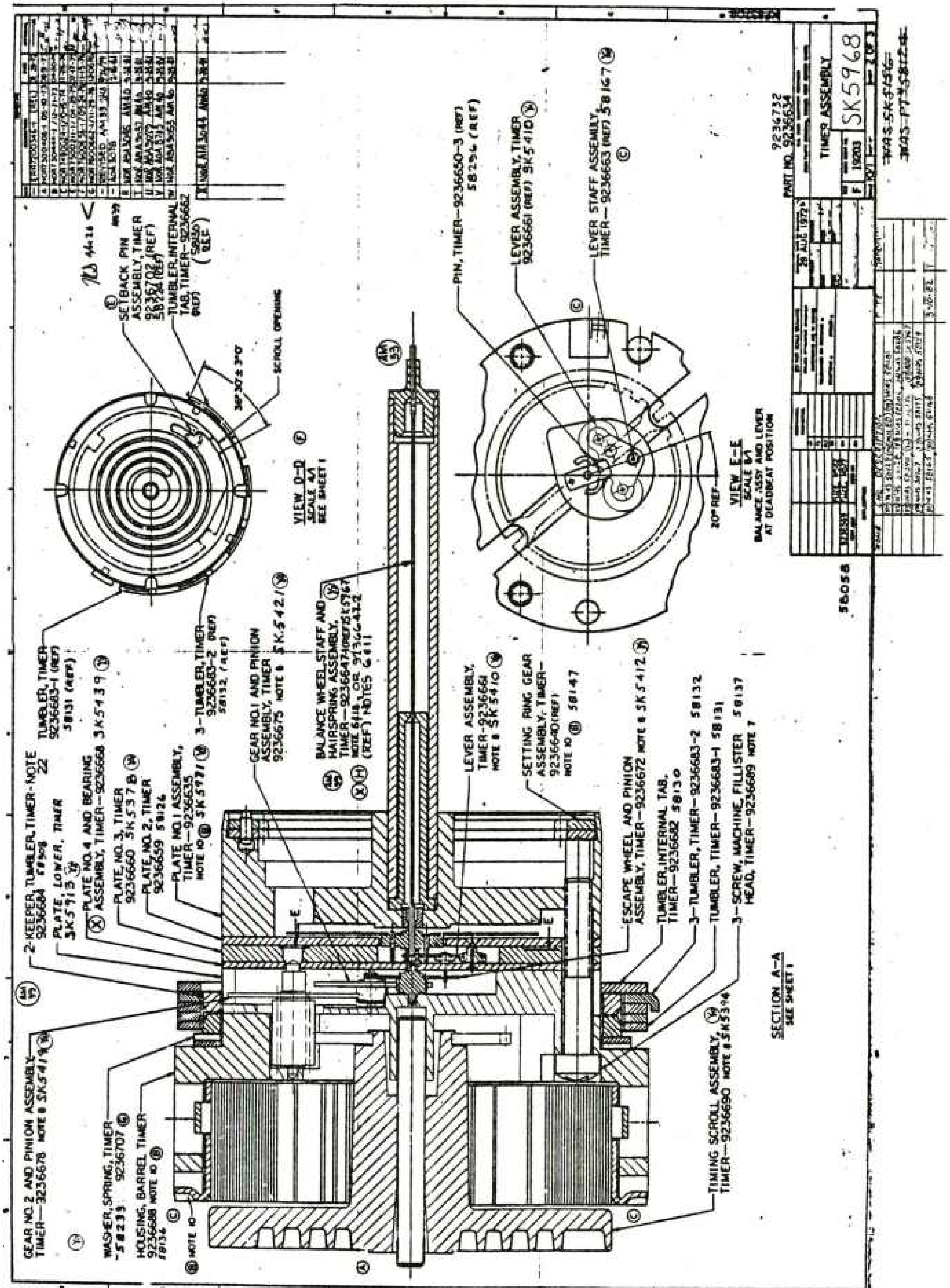
Tolerance study to determine the clearance between the top of the PIP designed Plate #1 and the Timer Housing. (Shown as Dimension Y.)

		+	-
Plate #1	(-) .412	-.010	
Plate #2	(-) .025	-.001	+.001
Plate #3	(-) .052	-.002	
Plate #4	(-) .0225	-.0035	
Lower Plate	(-) .136	-.002	+.002
Barrel Housing	(-) .562	-.003	
Mainspring Barrel	(-) .027	-.004	
Mainspring Barrel	(-) .006	-.002	+.002
Sleeve Washer	(-) .012	-.0015	
Sleeve	.805		-.004
Retainer Ring	(-) .035	-.002	.002
Timer Housing	(-) .056	-.006	
Timer Housing	.622		-.005
Timer Housing	(-) .052	-.004	

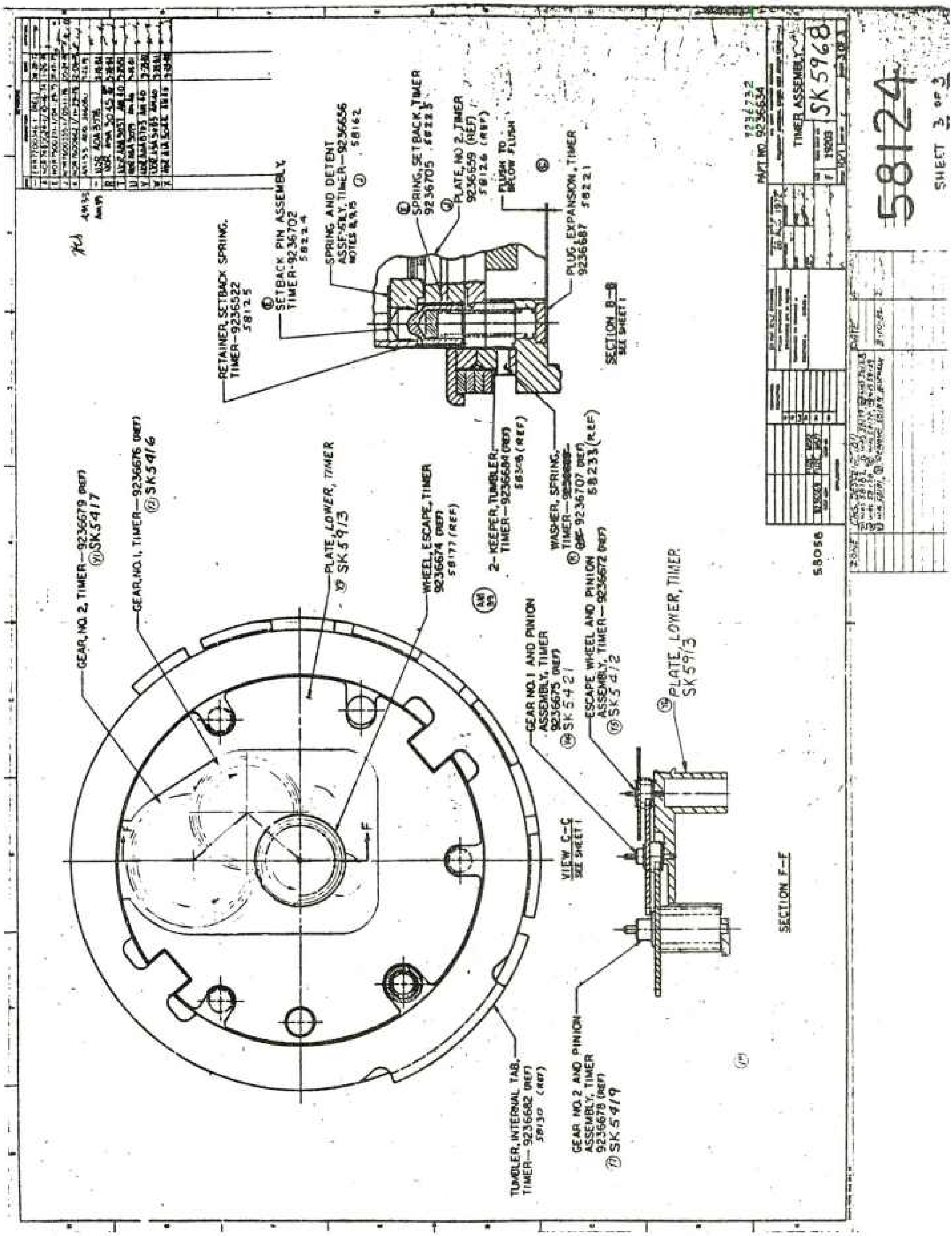
Y = .0295 +.041 -.011
Y = .0705/.0185

APPENDIX D
DRAWINGS


TIMING SCROLL ASSEMBLY, TIMER-9236690 (REF)
HOUSING, BARREL, TIMER 9236688 (REF)
PLATE NO.1 ASSEMBLY, TIMER-9236635 (REF)
STAKE, 2 PLCS MIN - NOTE 5
RETAINER, SETBACK SPRING, TIMER-9236522 (REF)
SPRING AND DETENT ASSEMBLY, TIMER 9236656 (REF)
SEE SHEET 2
SEE SHEET 3
NOTES CON'T:-
17-ALTERNATIVE:-THE TEETH OF THE TIMING SCROLL ASSEMBLY MAY BE LUBRICATED WITH GREASE-9236357.
18-THE REQUIREMENTS OF NOTE 9 MAY BE PERFORMED PRIOR TO THE ASSEMBLY OF THE TIMING SCROLL ASSY, TIMER, 9236690.
19-PRIOR TO REGULATION OF THE BEAT RATE IT IS PERMITTED TO RUN THE TIMER ASSY APPROX. 300 SECONDS WITH A TORQUE OF APPROX. 30 OUNCE INCHES OR WITH A TORQUE SUPPLIED BY TIMING SCROLL ASSEMBLY TIMER.
20-PLACE THE .50±.02 SECTION OF THE RETAINER SETBACK SPRING TIMER-9236522 THAT CONTAINS NO ADHESIVE OVER THE SPRING SETBACK, TIMER-9236705 (58725).
21.- SEE BELOW
NOTES:-
1-SPEC MIL-A-2550 APPLIES.
4-BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY SHOWN IN DETENTED POSITION, 90° COUNTER CLOCKWISE FROM DEADBEAT POSITION (VIEW E-E SHEET 2).
5-WIND MAINSPRING AND BARREL ASSEMBLY, TIMER 7 3/4 ± 1/4 TURNS. AFTER THE REQUIREMENTS OF NOTE 14 ARE MET, THE MAINSPRING AND BARREL ASSEMBLY, TIMER SHALL BE REWOUND TO 7 3/4 ± 1/4 TURNS AND STAKED SECURELY INTO HOUSING, BARREL, TIMER NOTCHES APPROX. AS SHOWN.
6-BEAT RATE OF BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY, TIMER TO BE 80.15 ± .10 BEATS PER SECOND MANDATORY. (SEE NOTE 11)
7-3-SCREWS, MACHINE, FILLISTER HEAD, TIMER TO BE TORQUED TO 5.5 + .5 INCH POUNDS. (NOTE 10)
8-LUBRICATE ALL PIVOTS AND TEETH OF THE FOLLOWING WITH OIL, LUBRICATING-9236485:-
A-SPRING AND DETENT ASSEMBLY, TIMER.
B-BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY, TIMER.
C-LEVER ASSEMBLY, TIMER.
D-ESCAPE WHEEL AND PINION ASSEMBLY, TIMER.
E-GEAR NO.1 AND PINION ASSEMBLY, TIMER.
F-GEAR NO.2 AND PINION ASSEMBLY, TIMER.
G-TIMING SCROLL ASSEMBLY, TIMER. (SEE NOTE 17)
9-SPRING AND DETENT ASSEMBLY, TIMER SHALL NOT FUNCTION OR RELEASE BALANCE WHEEL, STAFF & HAIRSPRING ASSEMBLY, TIMER AT 1000+25 RPM; SPRING AND DETENT ASSEMBLY, TIMER SHALL FUNCTION AND RELEASE BALANCE WHEEL STAFF AND HAIRSPRING ASSEMBLY, TIMER AT 2,000-25 RPM., NOTE 18.
10-ADVISORY-A FORCE OF APPROXIMATELY 2000 POUNDS TO BE APPLIED TO THE HOUSING BARREL TIMER IN AREA SHOWN WHILE PLATE NO.1 ASSEMBLY, TIMER IS SUPPORTED THROUGH THE SETTING RING GEAR ASSEMBLY, TIMER DURING THE ASSEMBLY OF THE 3-SCREWS, MACHINE, FILLISTER HEAD, TIMER.
12-AMPLITUDE OF BALANCE WHEEL TO BE 85° MIN (MANDATORY) AND 120° MIN (ADVISORY), NOTE 14 & 19.
NOTES CONTINUED:-
14-TIMER SHALL MAINTAIN MINIMUM AMPLITUDE WHILE RUNNING FOR A DURATION OF 30-40 SECONDS WITH THE MAINSPRING WOUND AS INDICATED IN NOTE 5 (NOTE 19).
15-ADVISORY: LUBRICATE FACE OF SPRING AND DETENT ASSEMBLY, TIMER ADJACENT TO PLATE NO. 2, TIMER WITH OIL, LUBRICATING-9236485.
16-ADVISORY: REGULATION OF THE BEAT RATE MAY BE ACCOMPLISHED BY PLACING 4 SETS (MAX) OF 2 HOLES, .010 MAX DIA AS REQD 180°±5° APART ON A
.720 DIA REF WHEN BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY, TIMER 9236687-2 IS USED (NOTE 11)
.755 DIA WHEN BALANCE WHEEL, STAFF & HAIRSPRING ASSEMBLY, TIMER 9236687-1 IS USED (NOTE 16)
REVISION STATUS OF SHEETS
TIMER ASSEMBLY
SK 5968
11-ADVISORY- WHEN BALANCE WHEEL, STAFF & HAIRSPRING ASSY, TIMER 9236687-2 IS USED: REGULATION OF THE BEAT RATE MAY BE ACCOMPLISHED BY PLACING 4 SETS (MAX) OF 2 HOLES, .015 MAX DIA AS REQD 180°±5° APART CENTERED ON THE .720 DIA OF THE BALANCE WHEEL. EACH SET OF HOLES WILL INCREASE THE BEAT RATE BY APPROX .1 BEATS PER SECOND.
.755 DIA. ON THE CENTER LINES OF THE BALANCE WHEEL. EACH SET OF HOLES WILL INCREASE THE BEAT RATE IN PROPORTION TO THEIR SIZE.
NOTES CONTINUED:-
21. ALTERNATIVE: ADHESIVE - 9271994-2 (58210) MAY BE USED.
22. DIE BREAK IN DIRECTION SHOWN.
WAS SK 8186
WAS PF 58124

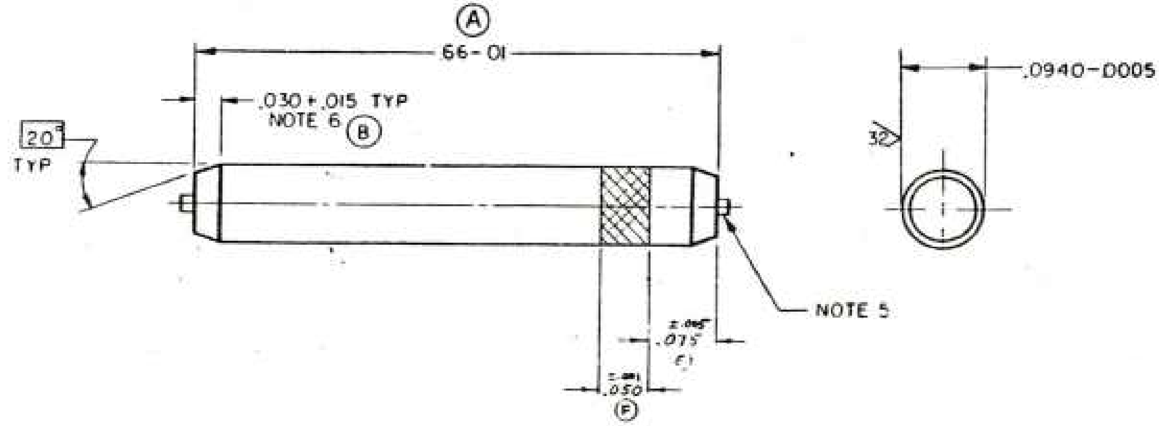


SECTION A-A
SEE SHEET 1
VIEW D-D
SCALE 4/1
SEE SHEET 1
VIEW E-E
SCALE 8/1
BALANCE ASSY AND LEVER AT DEADBEAT POSITION
SCROLL OPENING
GEAR NO.2 AND PINION ASSEMBLY, TIMER—9236678 NOTE 8 SK5419
WASHER, SPRING, TIMER—9236707
HOUSING, BARREL, TIMER—9236688 NOTE 10
TIMING SCROLL ASSEMBLY, TIMER—9236690 NOTE 8 SK5394
2-KEEPER, TUMBLER, TIMER—9236684
PLATE, LOWER, TIMER SK5913
PLATE NO.4 AND BEARING ASSEMBLY, TIMER—9236668 SK5439
PLATE, NO.3, TIMER 9236660 SK5378
PLATE, NO.2, TIMER 9236659
PLATE NO.1 ASSEMBLY, TIMER—9236635 NOTE 10 SK5971
TUMBLER, TIMER—9236683-1 (REF)
3-TUMBLER, TIMER—9236683-2 (REF)
GEAR NO.1 AND PINION ASSEMBLY, TIMER 9236675 NOTE 8 SK5421
BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY, TIMER—9236647
LEVER ASSEMBLY, TIMER—9236661 NOTE 8 SK5410
SETTING RING GEAR ASSEMBLY, TIMER—9236640 (REF) NOTE 10
ESCAPE WHEEL AND PINION ASSEMBLY, TIMER—9236672 NOTE 8 SK5412
TUMBLER, INTERNAL TAB, TIMER—9236682
3-TUMBLER, TIMER—9236683-2
TUMBLER, TIMER—9236683-1
3-SCREW, MACHINE, FILLISTER HEAD, TIMER—9236689 NOTE 7
SETBACK PIN ASSEMBLY, TIMER 9236702 (REF)
TUMBLER, INTERNAL TAB, TIMER—9236682
PIN, TIMER—9236650-3 (REF)
LEVER ASSEMBLY, TIMER 9236661 (REF) SK5410
LEVER STAFF ASSEMBLY, TIMER—9236663 (REF)
TIMER ASSEMBLY
PART NO. 9236634
SK5968



RETAINER, SETBACK SPRING, TIMER—9236522
58125
SETBACK PIN ASSEMBLY, TIMER-9236702
58224
SPRING AND DETENT ASSEMBLY, TIMER—9236656
58162
SPRING, SETBACK, TIMER
9236705
PLATE, NO 2, TIMER
9236659 (REF)
58126 (REF)
FLUSH TO BELOW FLUSH
PLUG, EXPANSION, TIMER
9236687 58221
SECTION B-B
SEE SHEET 1
GEAR, NO. 2, TIMER—9236679 (REF)
SK5417
GEAR, NO. 1, TIMER—9236676 (REF)
SK5416
PLATE, LOWER, TIMER
SK5913
WHEEL, ESCAPE, TIMER
9236674 (REF)
58177 (REF)
2-KEEPER, TUMBLER, TIMER—9236684 (REF)
58308 (REF)
WASHER, SPRING, TIMER
9236707 (REF)
58233 (REF)
GEAR NO. 1 AND PINION ASSEMBLY, TIMER
9236675 (REF)
SK5421
ESCAPE WHEEL AND PINION ASSEMBLY, TIMER—9236672 (REF)
SK5412
PLATE, LOWER, TIMER
SK5913
VIEW C-C
SEE SHEET 1
SECTION F-F
TUMBLER, INTERNAL TAB, TIMER—9236682 (REF)
58130 (REF)
GEAR NO. 2 AND PINION ASSEMBLY, TIMER
9236678 (REF)
SK5419
58058
PART NO. 9236634
9236732
TIMER ASSEMBLY
SK5968
58124
SHEET 3 OF 3

SYM	DESCRIPTION	DATE	APPR
—	ERR7200346-1 (REL)	08-28-72	—
A	NOR73C1405-1/12-28-73 NOR7400006-1/02-05-74	09-30-74	
B	NOR75C0163-1/02-25-75	06-30-75	
C	NORA8A2030 780825	780825	
D	NOTE 7 ADDED	2-1-84	
E/F	DIMENSIONS TO KNURL ADDED	2-1-84	
G	DATA INFO. BOX ADDED	2-1-84	



NOTES:-
1-SPEC MIL-A-2550 APPLIES.
2 MATERIAL:-FREE MACHINING STAINLESS AND HEAT-RESISTING STEEL WIRE, COLD FINISHED, TYPE 416 OR 416 Se, COND A, T OR H, ASTM A581.
3 ALTERNATIVE MATERIAL:-STAINLESS AND HEAT-RESISTING STEEL WIRE, COLD FINISHED, TYPE 410, ASTM A580.
4-125/ ALL OVER, EXCEPT AS NOTED.
5-.02 DIA MAX x .02 MAX LONG CUT OFF BURR PERMISSIBLE, BOTH ENDS.
6-KEY AUTOMATIC ASSEMBLY DIMENSION.
7-DIAMOND KNURL FINISH IN SHOWN SPECIFIED AREA.

G

DIAMOND KNURL DATA
PER ASA B94.6-1966

* DIAMETRAL PITCH	160
BLANK DIA.	.0940-.0005
MAX. KNURLED DIA.	.0945

* APPROXIMATE "TPI" IS 51.

A

		MECHANICAL PROPERTIES	
		YP	
		TS	
		ELZ	
C 9236712	FUZE, M582	RA	
9236635	FUZE, M577	KNOOP HARDNESS 278-405 (500 GRAM LOAD)	
NEXT ASSY	USED ON		
APPLICATION			

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

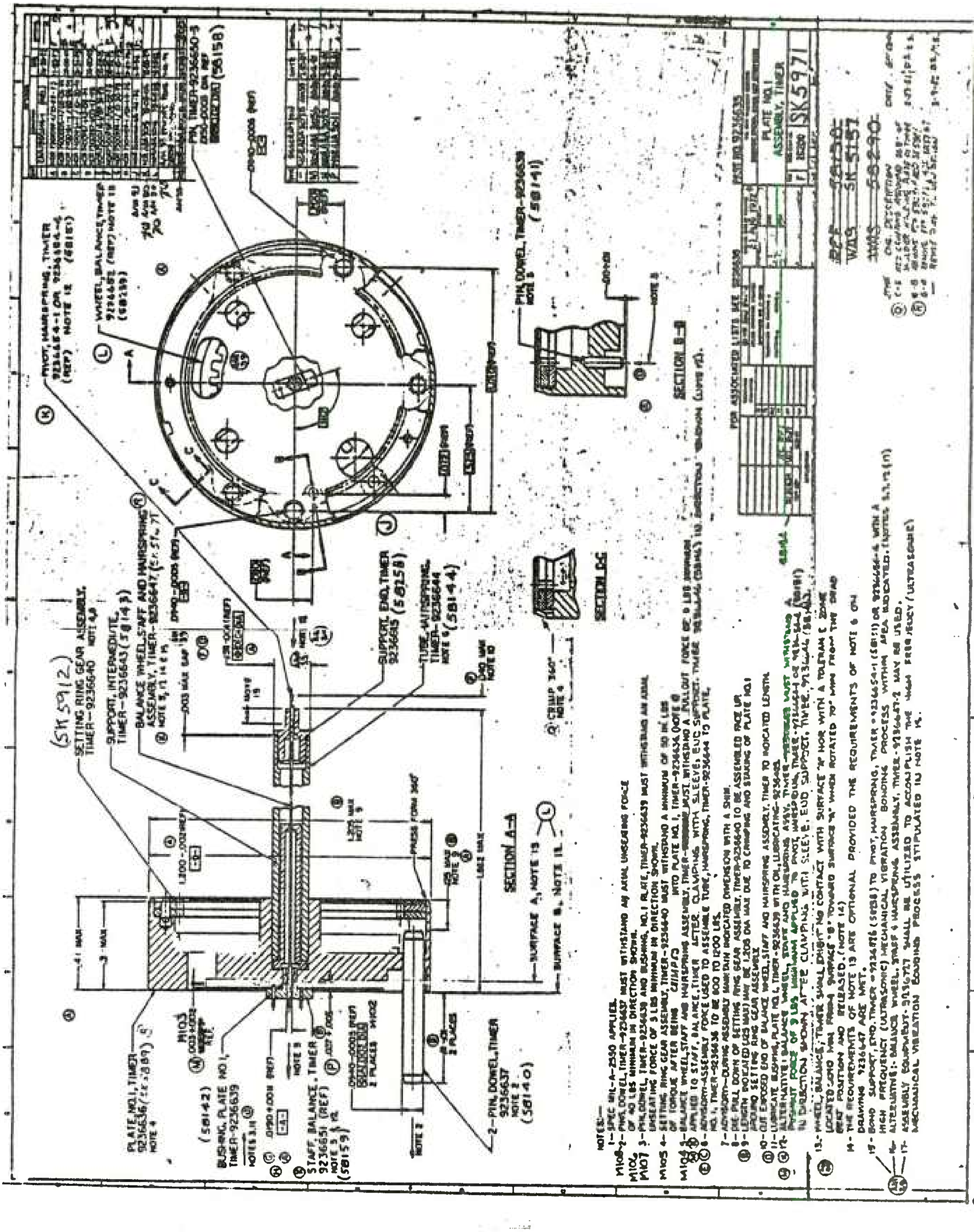
ORIGINAL DATE OF DRAWING 28 AUG 1972
DRAFTSMAN | CHECKER
ENGR | ENGR
ENGR | ENGR

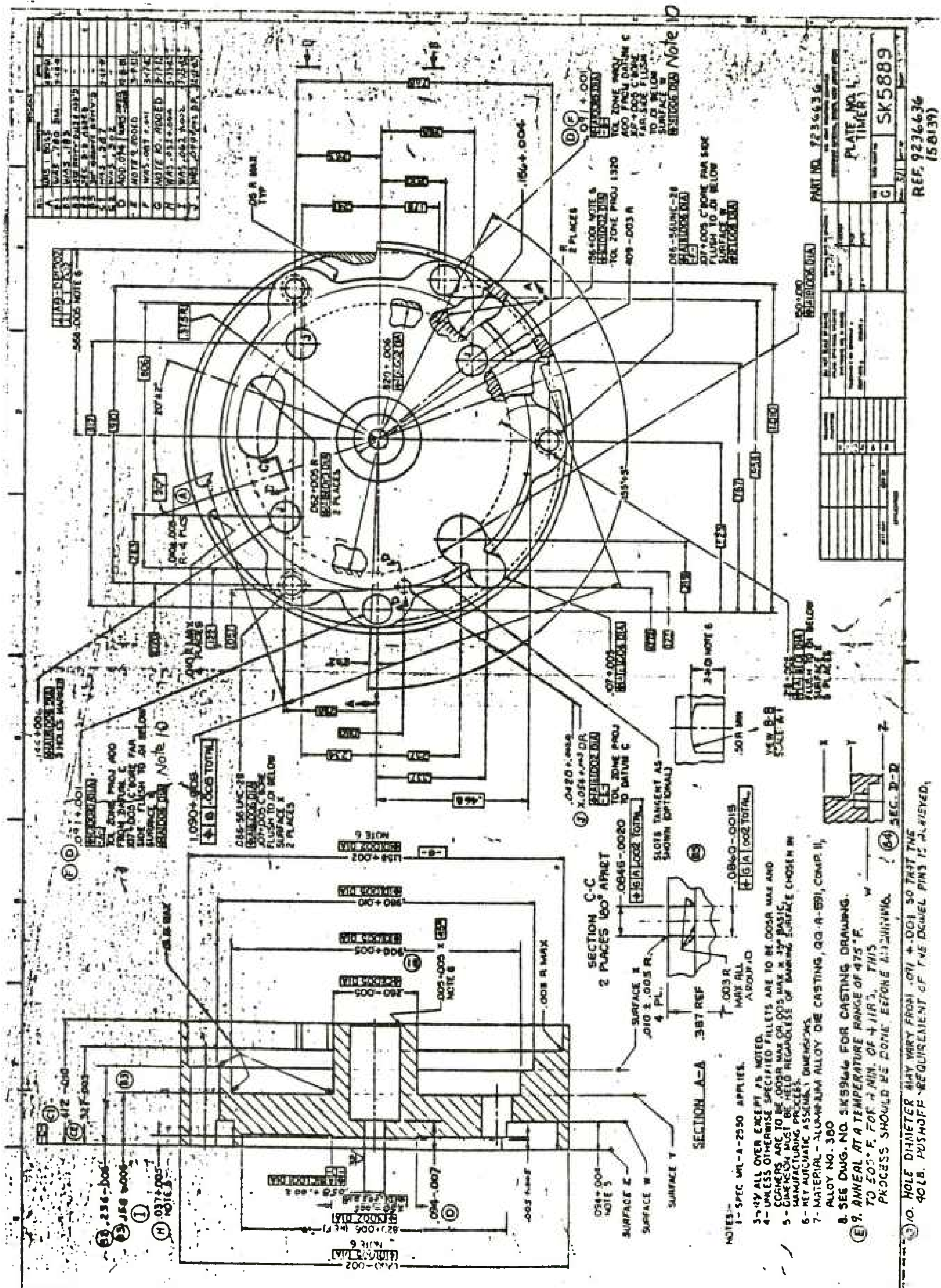
PART NO. ~~9236637~~
U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMD.
DOVER, NEW JERSEY 07801

PIN, DOWEL, TIMER

SIZE C | CODE IDENT NO 19200 | ~~9236637~~
SCALE 10/1 | UNIT WT. | SHEET

SK 6357


SECTION A-A
SECTION B-B
SECTION C-C
PLATE NO. 1
ASSEMBLY, TIMER
SK5971



GEAR DATA	
NUMBER OF TEETH	60
DIAMETRAL PITCH	64
PRESSURE ANGLE	20°
PITCH DIAMETER	.9375
TOOTH FORM	INVOLUTE
TOTAL COMPOSITE ERROR (NOTES 8, 11)	.0020
TOOTH TO TOOTH COMP ERROR (NOTE 11)	.0010
MAJOR DIAMETER (REF)	.979
CIRCULAR TOOTH THICKNESS	.0245
AGMA PRECISION CLASS (REF)	1A

M101

TABLE

PART NO.	DIM A	DIM B	QUANTITY
236642-1103I-002	.02 MIN	2 REQ	
[illegible]	[illegible]	[illegible]	[illegible]

REF.

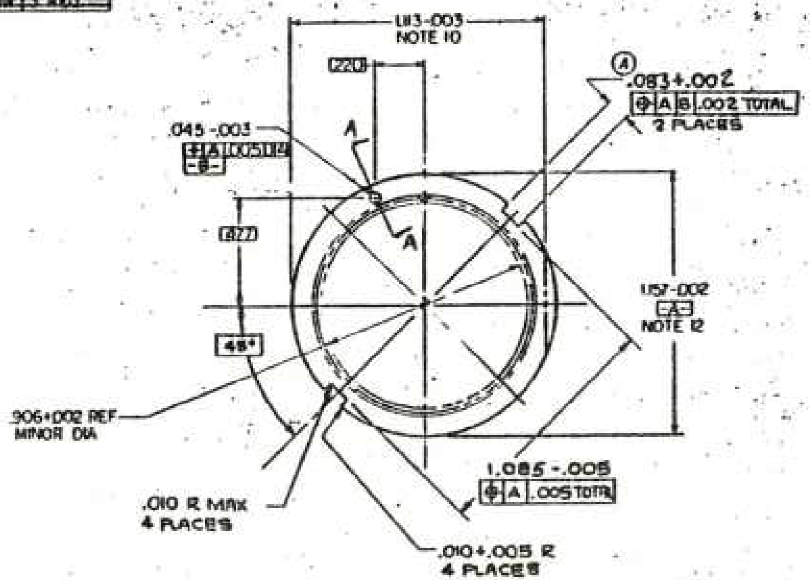
NOTES:- (CONT)

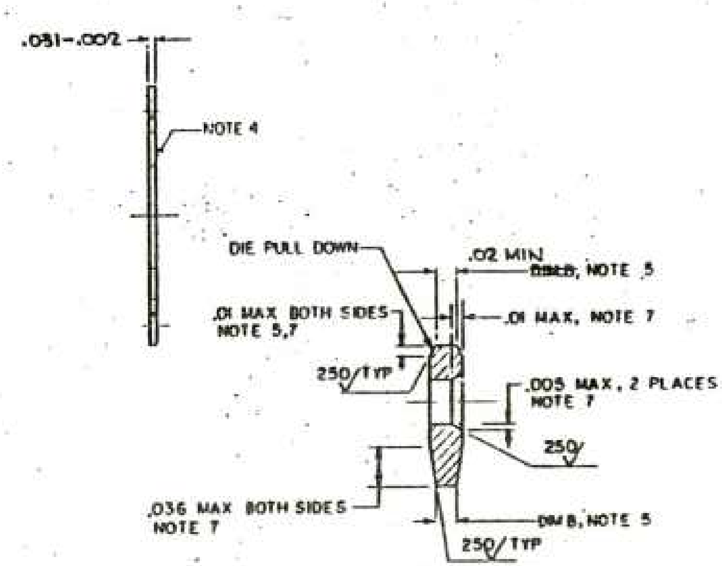
12 - 1.158 MAX DIA PERMITTED PROVIDED THE REQUIREMENTS OF DWG 9236635 ARE MET.

13 - ALTERNATIVE MATERIAL:-HIGH STRENGTH STAINLESS AND HEAT-RESISTING CHROMIUM-NICKEL STEEL SHEET AND STRIP, TYPE 301, COLD-ROLLED, 1/4 HARD MIN, ASTM A177.

14 - 1.113 DIMENSION OPTIONAL, EXCEPT FOR COMPONENTS TO BE ASSEMBLED ON AUTOMATIC TIMER ASSEMBLY EQUIPMENT.

M201





SECTION A-A

SCALE 20/1

NOTES:-

1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL:-STAINLESS AND HEAT-RESISTING CHROMIUM-NICKEL STEEL PLATE, SHEET AND STRIP, TYPE 301, ASTM A167. (SEE NOTE 13)
3 - 125 ALL OVER EXCEPT 63 ON FACE AND FLANKS OF TEETH UNLESS OTHERWISE SPECIFIED.
4 - PART MAY BE CONCAVE OR CONVEX WITHIN .005.
5 - PERMITTED AROUND ENTIRE INTERNAL AND EXTERNAL PROFILE.
6 - UNLESS OTHERWISE SPECIFIED FILLETS ARE TO BE .005R MAX AND CORNERS ARE TO BE .005R MAX OR .005 MAX × 45° BASIC.
7 - PERMISSIBLE DRAWDOWN AND/OR DIEBREAK ZONE.
8 - TOTAL COMPOSITE ERROR APPLIES WITH RESPECT TO -A-.
9 -
10 - KEY AUTOMATIC ASSEMBLY DIMENSION.
11 - .003 TOTAL COMPOSITE ERROR AND .002 TOOTH TO TOOTH COMPOSITE ERROR PERMITTED PROVIDED THE REQUIREMENTS OF DRAWINGS 9236569, 9236500 AND 9236700 ARE MET.

PART NO. SEE TABLE

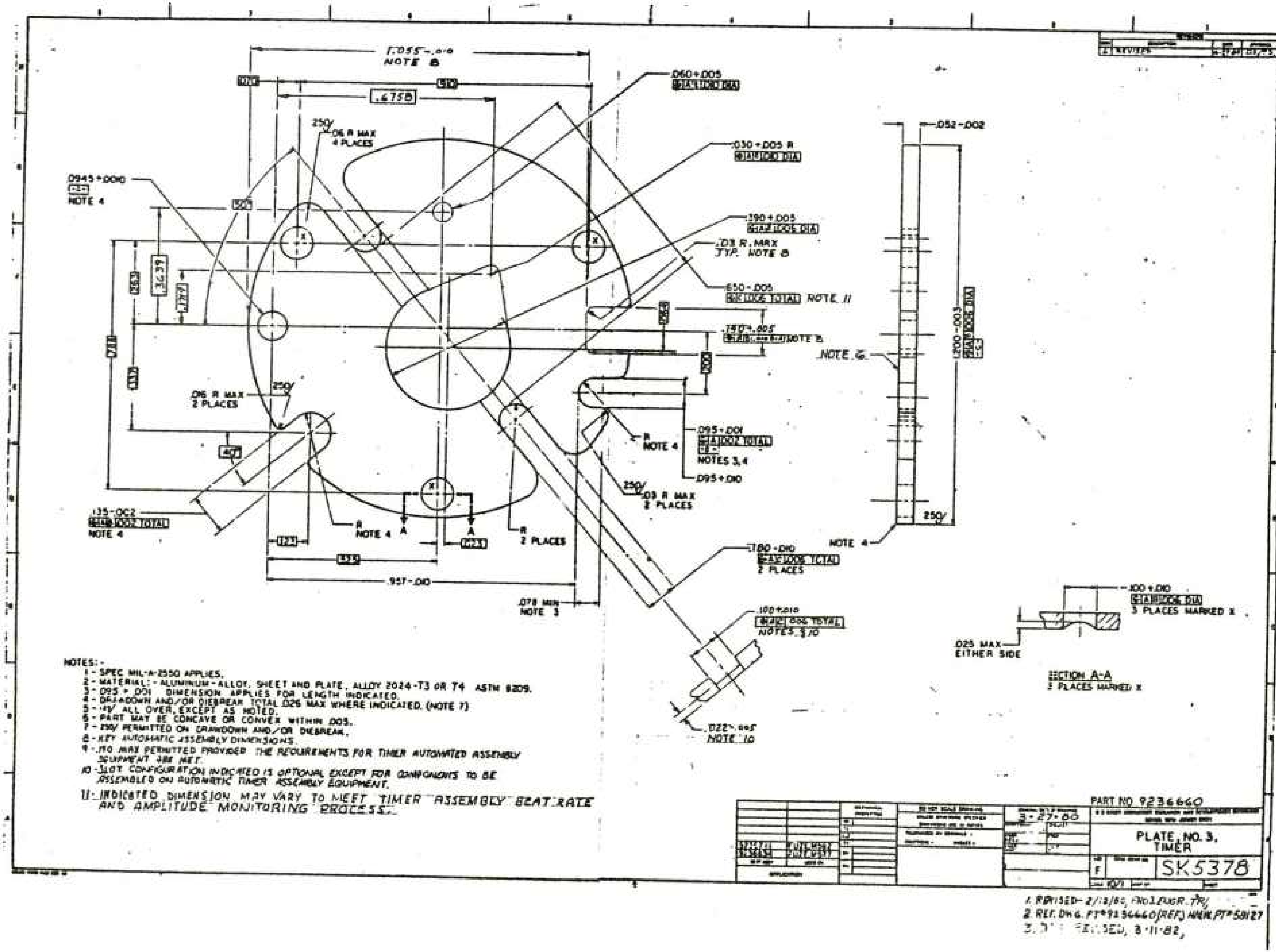
GEAR, SETTING RING, TIMER

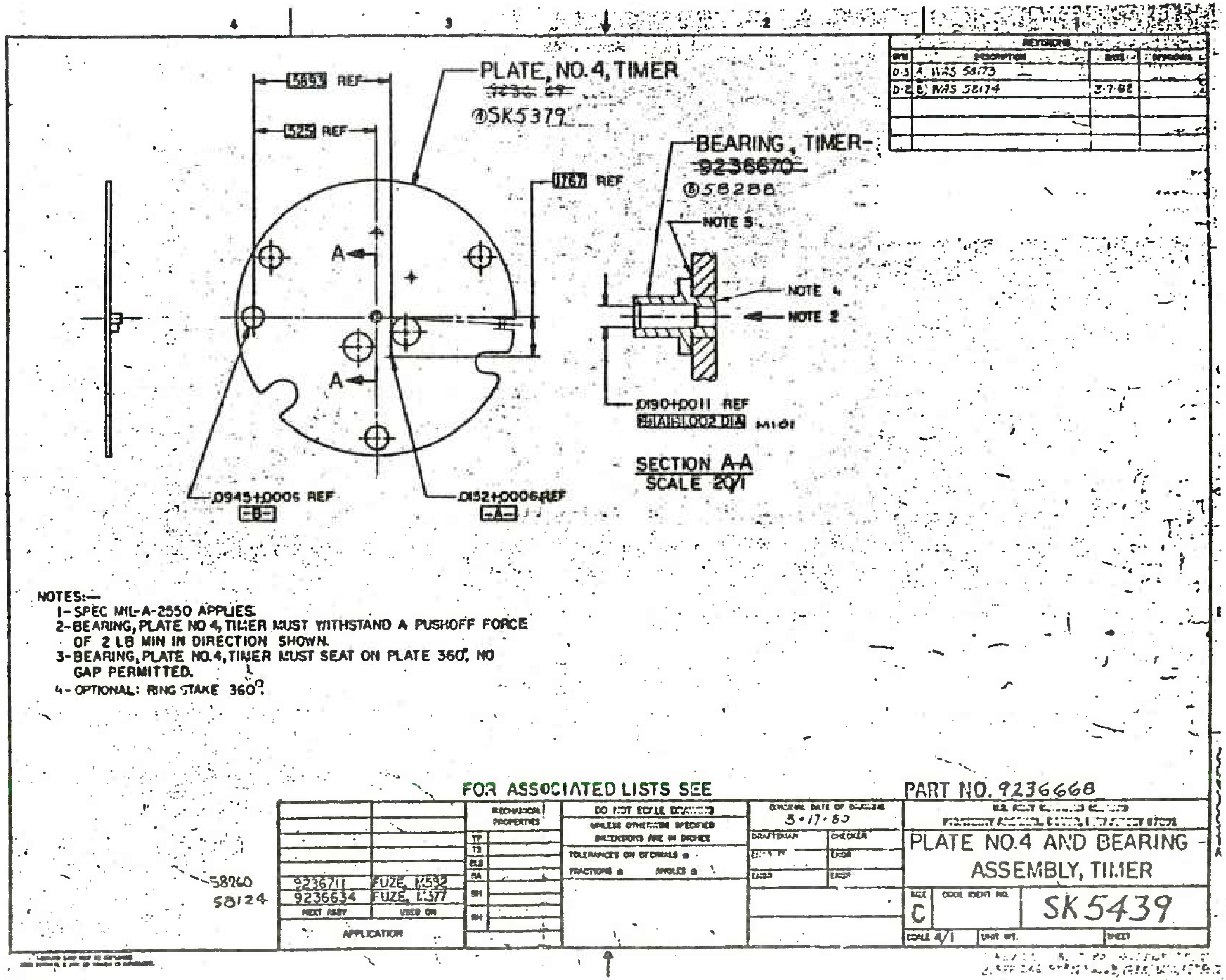
D 19200 SK5912

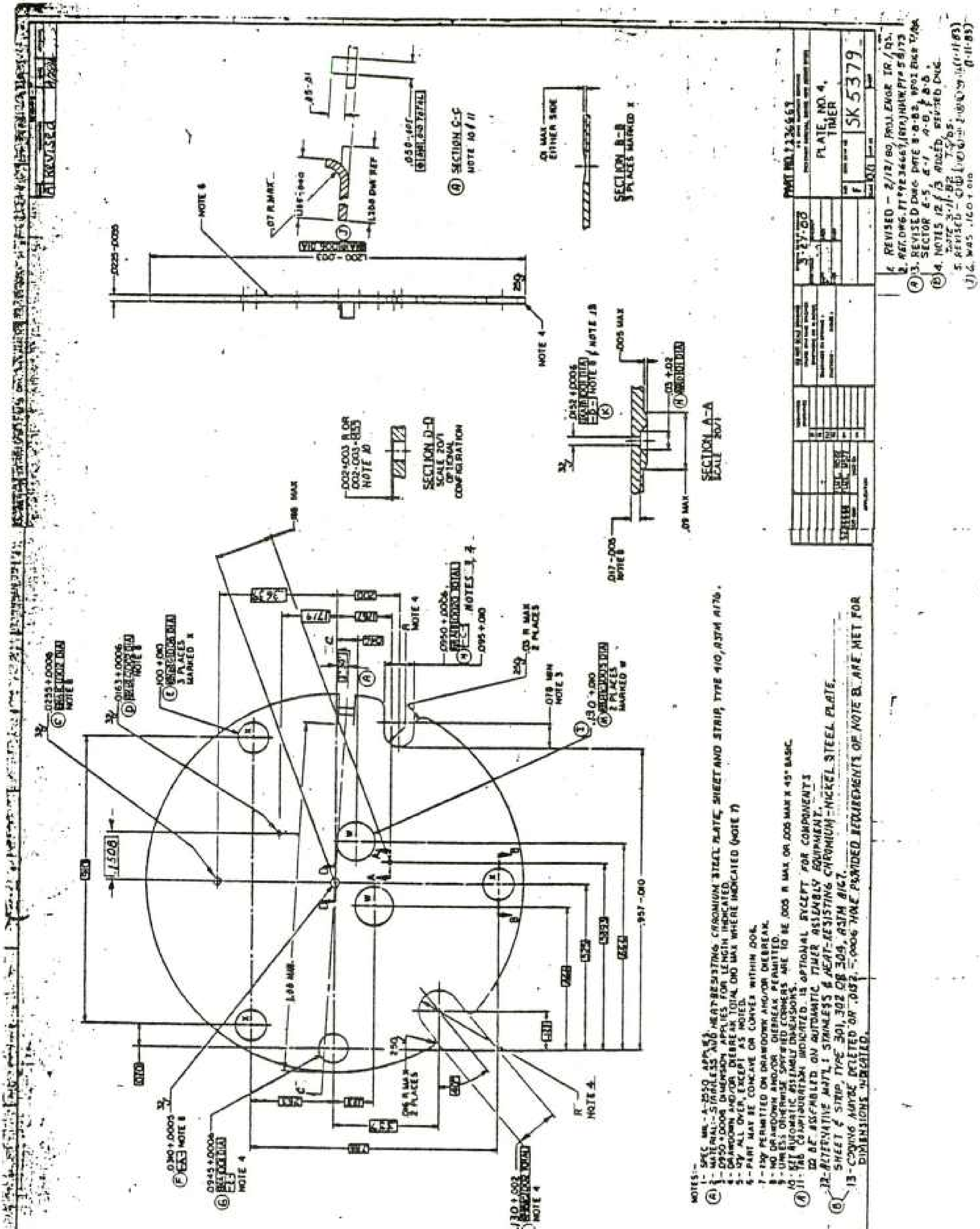
10 SEPT, 81

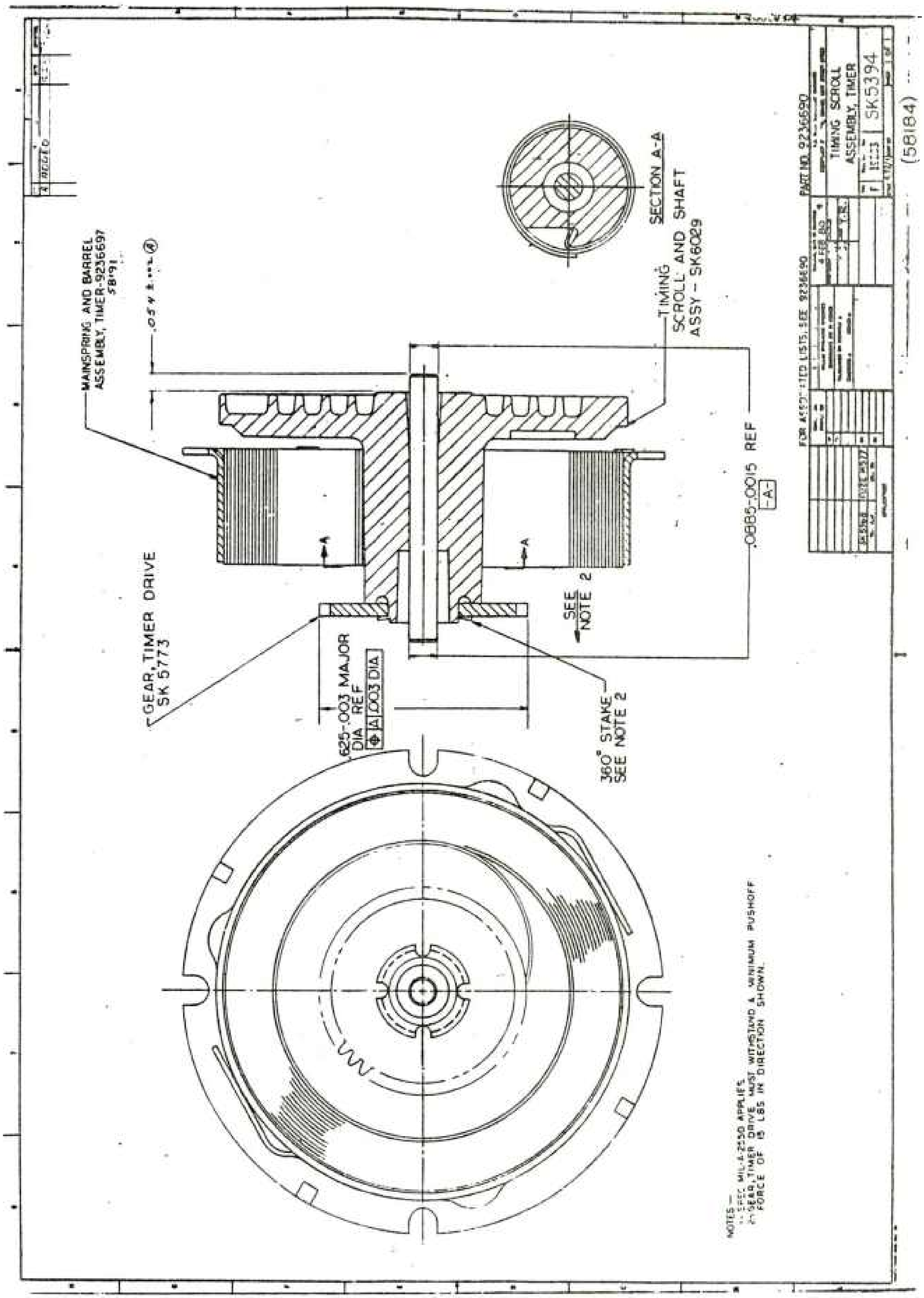
ZONE	SYM	DESCRIPTION	DATE
C-3	A	WAS .087 MIN	3-17-82

9236642

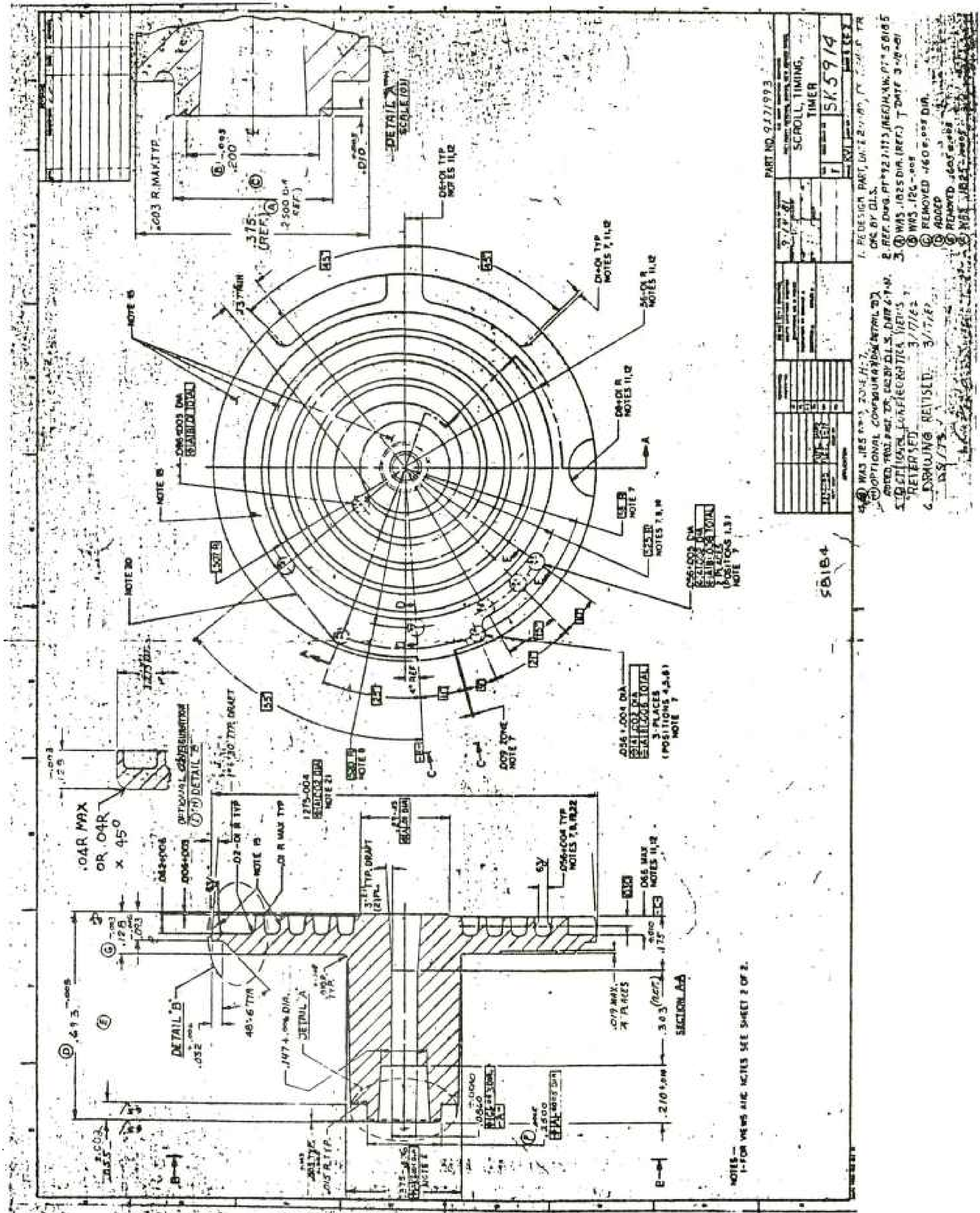

NOTES:-
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL:- ALUMINUM-ALLOY, SHEET AND PLATE, ALLOY 2024-T3 OR T4 ASTM B209.
3 - .095 + .001 DIMENSION APPLIES FOR LENGTH INDICATED.
4 - DRAWDOWN AND/OR DIEBREAK TOTAL .026 MAX WHERE INDICATED. (NOTE 7)
5 - 125/ ALL OVER, EXCEPT AS NOTED.
6 - PART MAY BE CONCAVE OR CONVEX WITHIN .003.
7 - 250/ PERMITTED ON DRAWDOWN AND/OR DIEBREAK.
8 - KEY AUTOMATIC ASSEMBLY DIMENSIONS.
9 - .110 MAX PERMITTED PROVIDED THE REQUIREMENTS FOR TIMER AUTOMATED ASSEMBLY EQUIPMENT ARE MET.
10 - SLOT CONFIGURATION INDICATED IS OPTIONAL EXCEPT FOR COMPONENTS TO BE ASSEMBLED ON AUTOMATIC TIMER ASSEMBLY EQUIPMENT.
11 - INDICATED DIMENSION MAY VARY TO MEET TIMER ASSEMBLY BEAT RATE AND AMPLITUDE MONITORING PROCESS.
SECTION A-A
3 PLACES MARKED X
.025 MAX EITHER SIDE
PART NO 9236660
PLATE, NO. 3, TIMER
SK5378
3-27-80
1. REVISED - 2/13/80, PROJ ENGR. TR/
2. REF. DWG. PT#9236660 (REF) MARK PT#58127
3. [illegible] REVISED, 3-11-82,

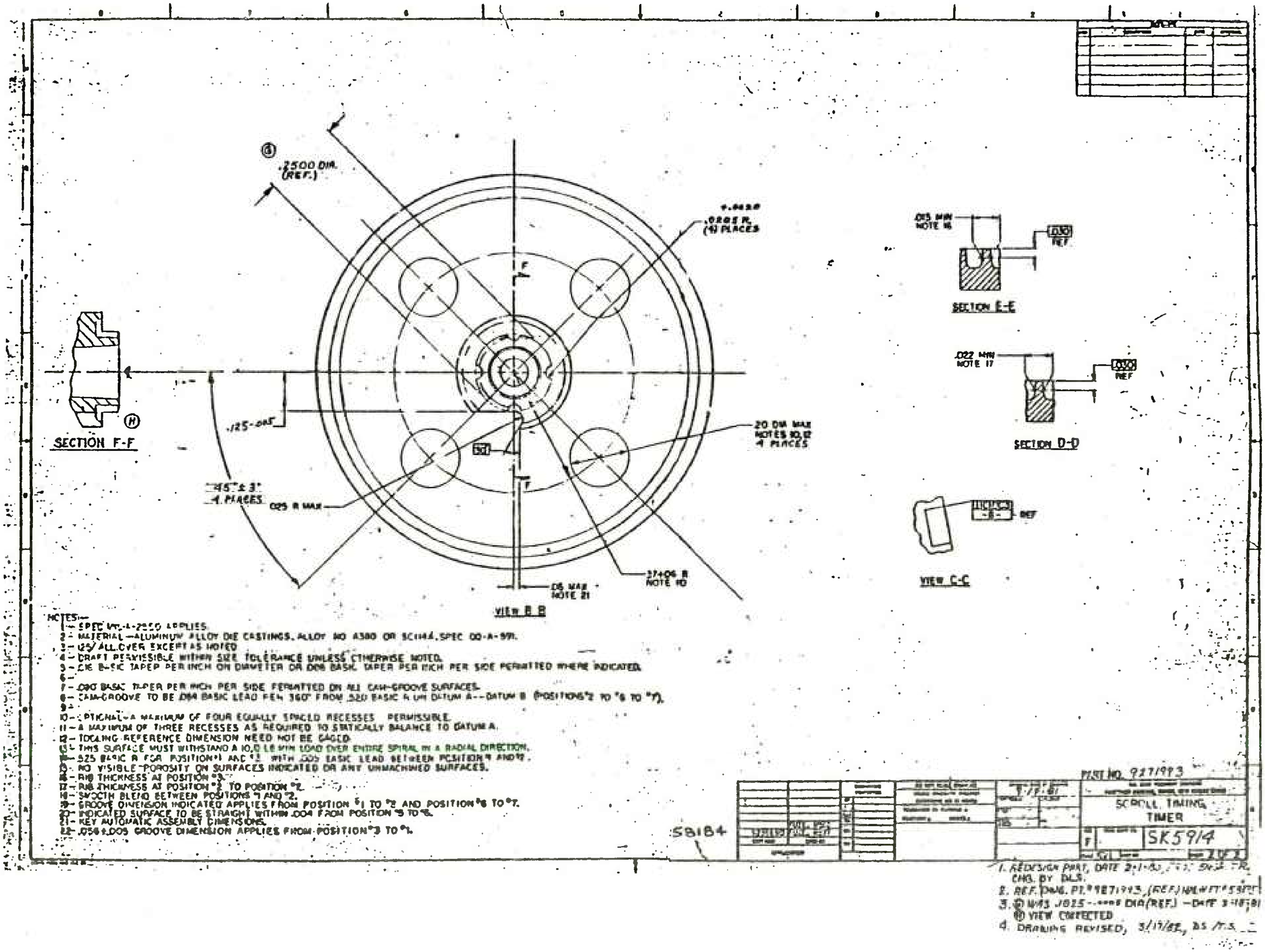

PLATE, NO. 4, TIMER
®SK5379
.5893 REF
.525 REF
.1767 REF
BEARING, TIMER-
~~9236670~~
®58288
NOTE 5
NOTE 4
NOTE 2
.0190+.0011 REF
.0945+.0006 REF
-B-
.0152+.0006 REF
-A-
SECTION A-A
SCALE 20/1
NOTES:—
1-SPEC MIL-A-2550 APPLIES.
2-BEARING, PLATE NO 4, TIMER MUST WITHSTAND A PUSHOFF FORCE OF 2 LB MIN IN DIRECTION SHOWN.
3-BEARING, PLATE NO.4, TIMER MUST SEAT ON PLATE 360°, NO GAP PERMITTED.
4-OPTIONAL: RING STAKE 360°.
REVISIONS
D-3 A WAS 58173
D-2 B WAS 58174 3-7-82
FOR ASSOCIATED LISTS SEE
PART NO. 9236668
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
3-17-80
PLATE NO.4 AND BEARING ASSEMBLY, TIMER
C
SK5439
SCALE 4/1
58260 9236711 FUZE, M592
58124 9236634 FUZE, M577
NEXT ASSY
USED ON
APPLICATION

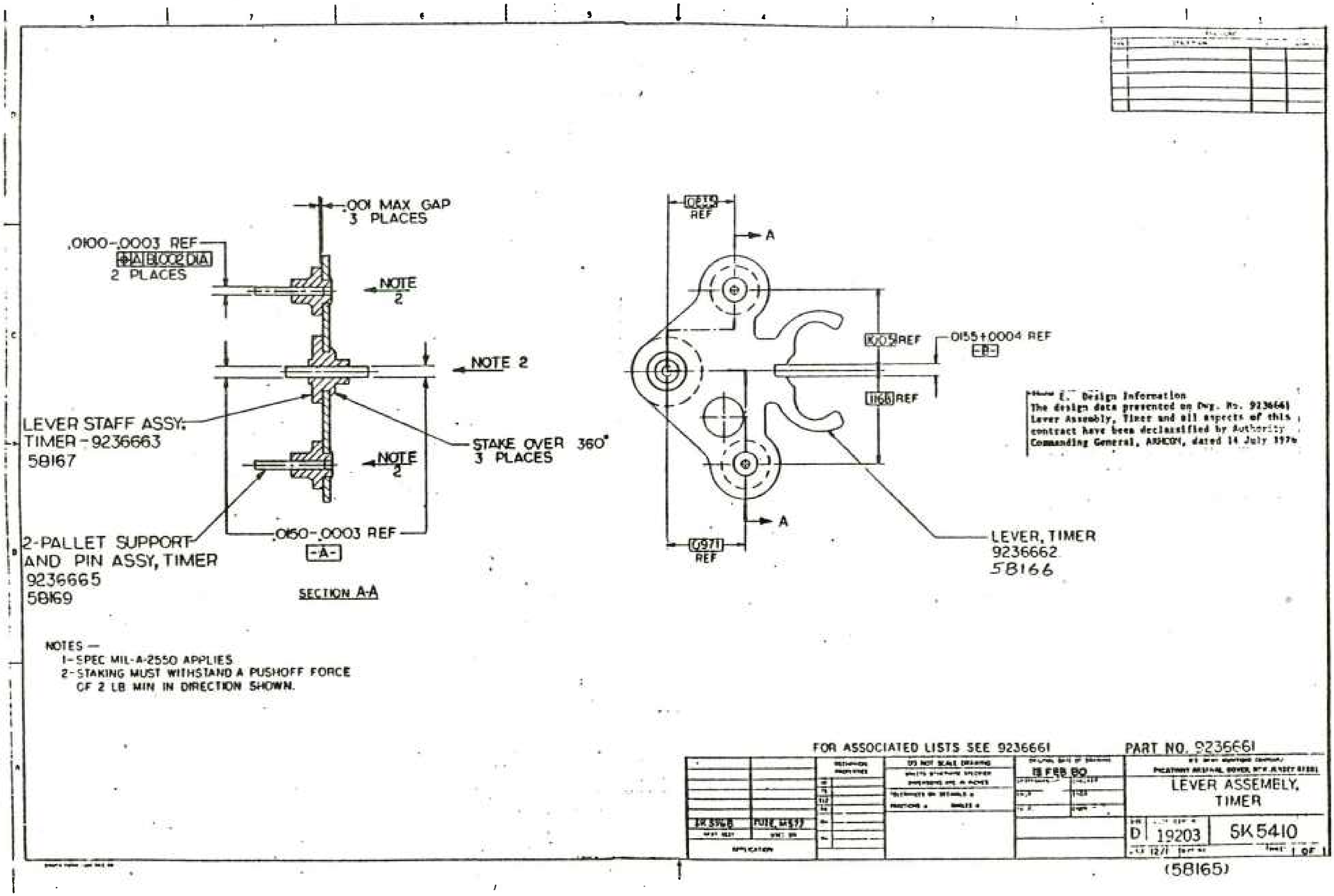

PLATE, NO. 4, TIMER
SK 5379
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D



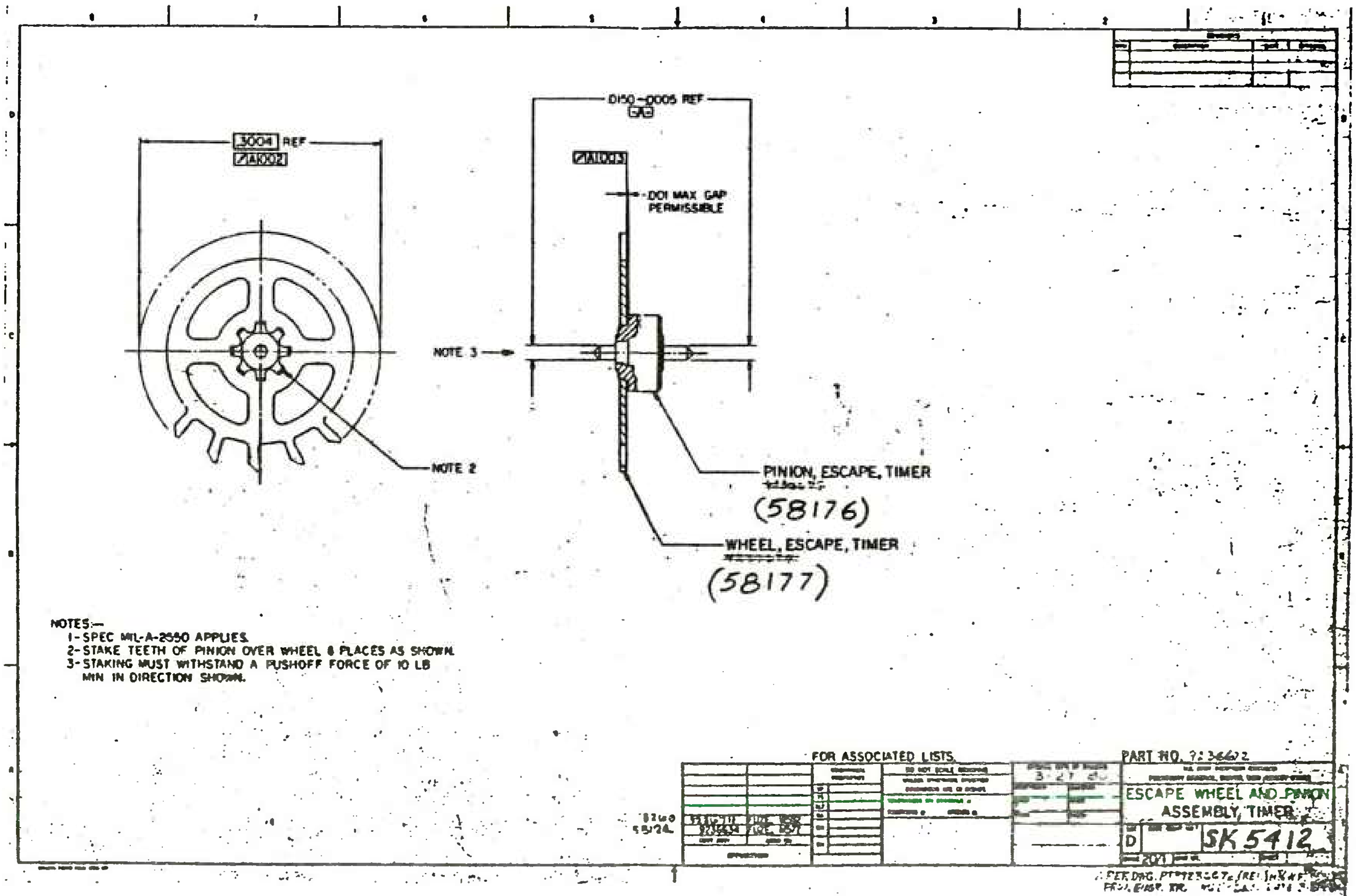
MAINSPRING AND BARREL ASSEMBLY, TIMER-9236697
58191
TIMING SCROLL AND SHAFT ASSY - SK6029
SECTION A-A
GEAR, TIMER DRIVE SK 5773
.625-.003 MAJOR DIA REF
.0885-.0015 REF
-A-
SEE NOTE 2
360° STAKE SEE NOTE 2
NOTES —
1- SPEC MIL-A-2550 APPLIES
2- GEAR, TIMER DRIVE MUST WITHSTAND A MINIMUM PUSHOFF FORCE OF 15 LBS IN DIRECTION SHOWN.
FOR ASSOCIATED LISTS, SEE 9236690
PART NO. 9236690
TIMING SCROLL ASSEMBLY, TIMER
SK5394
(58184)

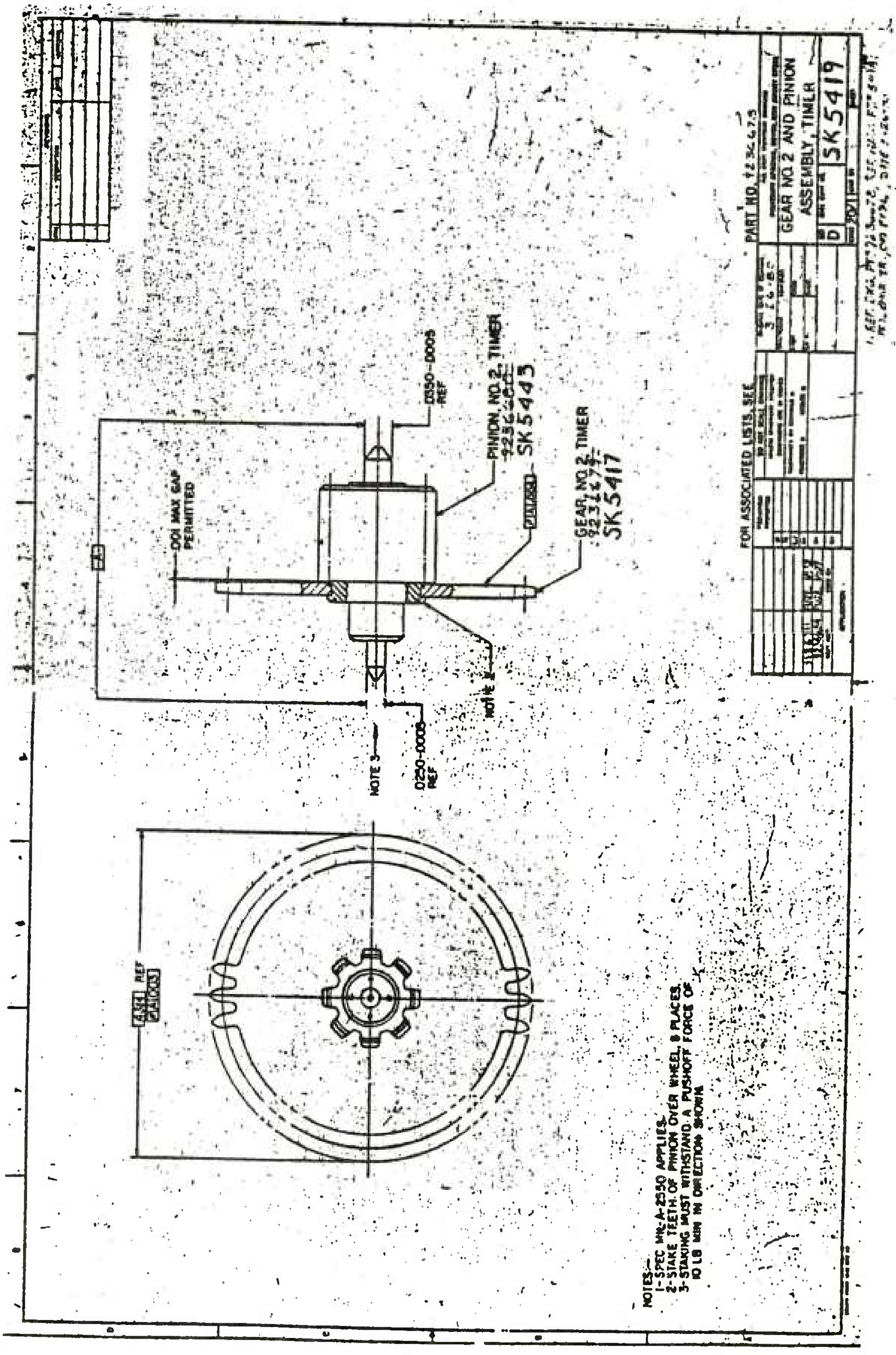

SCROLL, TIMING, TIMER
SK5914
SECTION A-A
DETAIL "A"
DETAIL "B"


.2500 DIA. (REF.)
.0285 R. (4) PLACES
20 DIA MAX NOTES 10, 12 4 PLACES
SECTION F-F
.125-.005
45° ± 3° 4 PLACES
.025 R MAX
.37±.06 R NOTE 10
.05 MAX NOTE 21
VIEW B-B
.015 MIN NOTE 16
.030 REF
SECTION E-E
.022 MIN NOTE 17
.030 REF
SECTION D-D
REF
VIEW C-C
NOTES—
1 — SPEC MIL-A-2550 APPLIES.
2 — MATERIAL—ALUMINUM ALLOY DIE CASTINGS, ALLOY NO A380 OR SC114A, SPEC QQ-A-591.
3 — 125/ ALL OVER EXCEPT AS NOTED
4 — DRAFT PERMISSIBLE WITHIN SIZE TOLERANCE UNLESS OTHERWISE NOTED.
5 — DIE BASIC TAPER PER INCH ON DIAMETER OR .008 BASIC TAPER PER INCH PER SIDE PERMITTED WHERE INDICATED.
6 —
7 — .030 BASIC TAPER PER INCH PER SIDE PERMITTED ON ALL CAM-GROOVE SURFACES.
8 — CAM-GROOVE TO BE .084 BASIC LEAD PER 360° FROM .520 BASIC R ON DATUM A—DATUM B (POSITIONS 2 TO 6 TO 7).
9 —
10 — OPTIONAL—A MAXIMUM OF FOUR EQUALLY SPACED RECESSES PERMISSIBLE.
11 — A MAXIMUM OF THREE RECESSES AS REQUIRED TO STATICALLY BALANCE TO DATUM A.
12 — TOOLING REFERENCE DIMENSION NEED NOT BE GAGED.
13 — THIS SURFACE MUST WITHSTAND A 10.0 LB MIN LOAD OVER ENTIRE SPIRAL IN A RADIAL DIRECTION.
14 — .525 BASIC R FOR POSITION 1 AND 2 WITH .005 BASIC LEAD BETWEEN POSITION 1 AND 2.
15 — NO VISIBLE POROSITY ON SURFACES INDICATED OR ANY UNMACHINED SURFACES.
16 — RIB THICKNESS AT POSITION 3.
17 — RIB THICKNESS AT POSITION 2 TO POSITION 2.
18 — SMOOTH BLEND BETWEEN POSITIONS 1 AND 2.
19 — GROOVE DIMENSION INDICATED APPLIES FROM POSITION 1 TO 2 AND POSITION 6 TO 7.
20 — INDICATED SURFACE TO BE STRAIGHT WITHIN .004 FROM POSITION 5 TO 6.
21 — KEY AUTOMATIC ASSEMBLY DIMENSIONS.
22 — .056±.005 GROOVE DIMENSION APPLIES FROM POSITION 3 TO 1.
58184
PART NO. 937/993
SCROLL, TIMING, TIMER
SK5914
2 OF 2
1. REDESIGN PART, DATE 2-1-81
CHG. BY DLS.
2. REF. DWG. PT. 937/993
3. WAS .1025 DIA (REF.)
VIEW CORRECTED
4. DRAWING REVISED, 3/17/82, DS



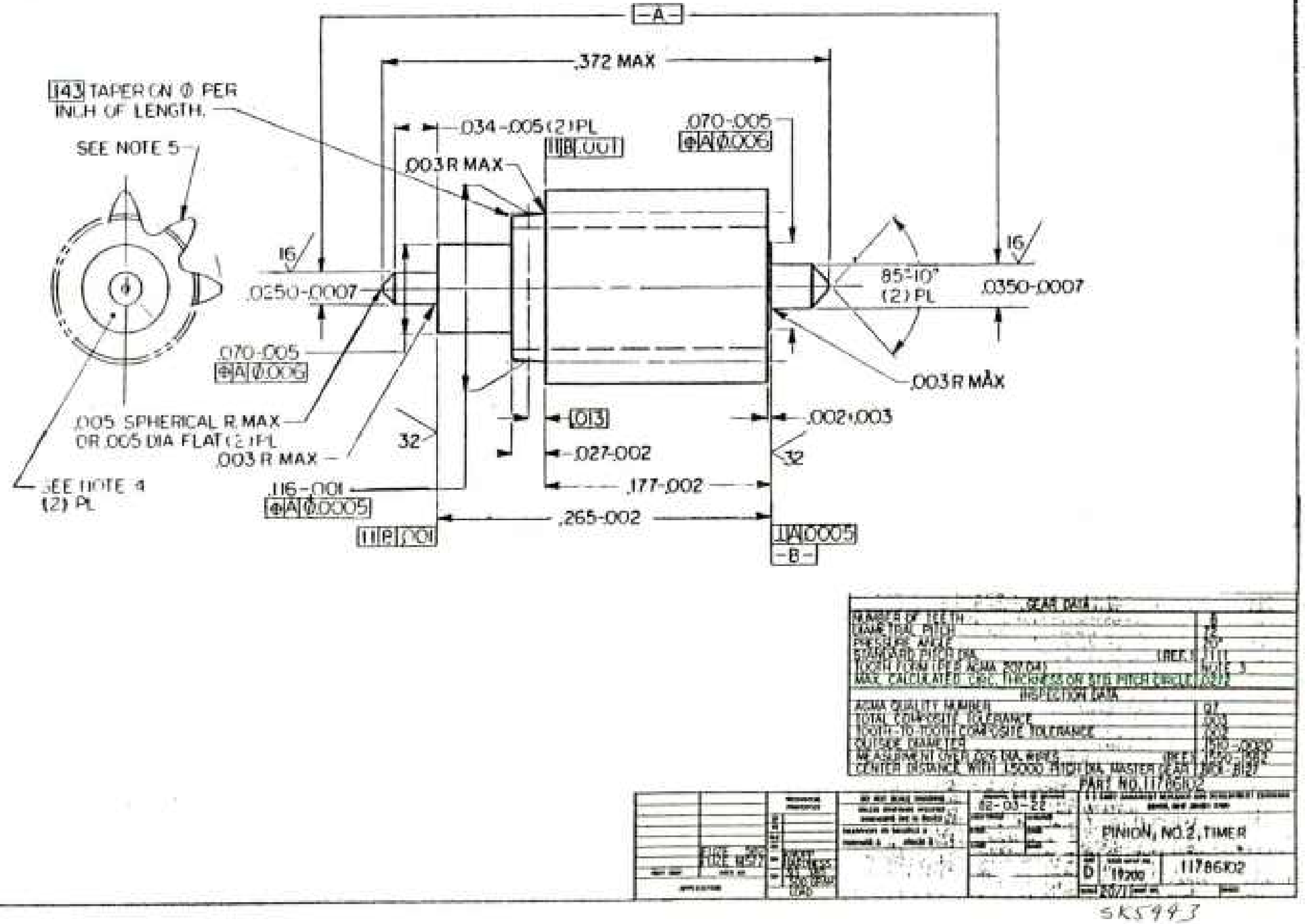
.001 MAX GAP
3 PLACES
.0100-.0003 REF
2 PLACES
NOTE 2
LEVER STAFF ASSY. TIMER - 9236663
58167
STAKE OVER 360°
3 PLACES
2-PALLET SUPPORT AND PIN ASSY, TIMER
9236665
58169
.0150-.0003 REF
-A-
SECTION A-A
NOTES —
1-SPEC MIL-A-2550 APPLIES
2-STAKING MUST WITHSTAND A PUSHOFF FORCE OF 2 LB MIN IN DIRECTION SHOWN.
A
REF
.0155+.0004 REF
-B-
LEVER, TIMER
9236662
58166
Note E: Design Information
The design data presented on Dwg. No. 9236661 Lever Assembly, Timer and all aspects of this contract have been declassified by Authority Commanding General, ARRCOM, dated 14 July 1976
FOR ASSOCIATED LISTS SEE 9236661
PART NO. 9236661
18 FEB 80
LEVER ASSEMBLY, TIMER
D
19203
SK5410
1 OF 1
(58165)

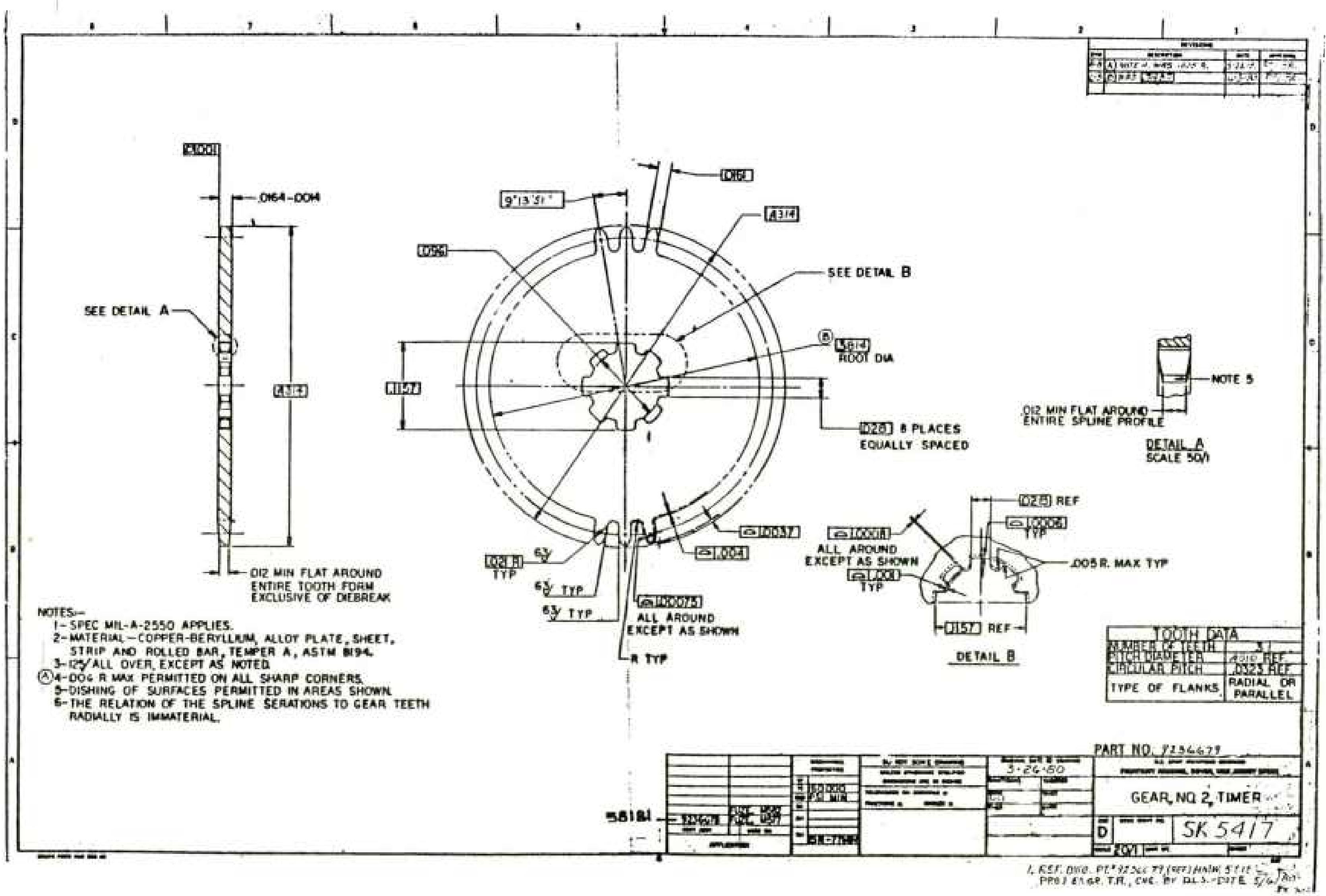

.3004 REF
.A.002
D150-.0005 REF
.A.003
.001 MAX GAP PERMISSIBLE
NOTE 3
NOTE 2
PINION, ESCAPE, TIMER
(58176)
WHEEL, ESCAPE, TIMER
(58177)
NOTES:—
1-SPEC MIL-A-2550 APPLIES.
2-STAKE TEETH OF PINION OVER WHEEL 8 PLACES AS SHOWN.
3-STAKING MUST WITHSTAND A PUSHOFF FORCE OF 10 LB MIN IN DIRECTION SHOWN.
FOR ASSOCIATED LISTS
PART NO.
ESCAPE WHEEL AND PINION ASSEMBLY, TIMER
D
SK 5412


.001 MAX GAP PERMITTED
.0350-.0005 REF
PINION, NO.2, TIMER
SK5443
GEAR, NO.2, TIMER
SK5417
NOTE 3
NOTE 2
.0250-.0005 REF
REF
NOTES—
1-SPEC MIL-A-2550 APPLIES.
2-STAKE TEETH OF PINION OVER WHEEL, 8 PLACES.
3-STAKING MUST WITHSTAND A PUSHOFF FORCE OF 10 LB MIN IN DIRECTION SHOWN.
FOR ASSOCIATED LISTS, SEE
GEAR NO.2 AND PINION ASSEMBLY, TIMER
SK5419

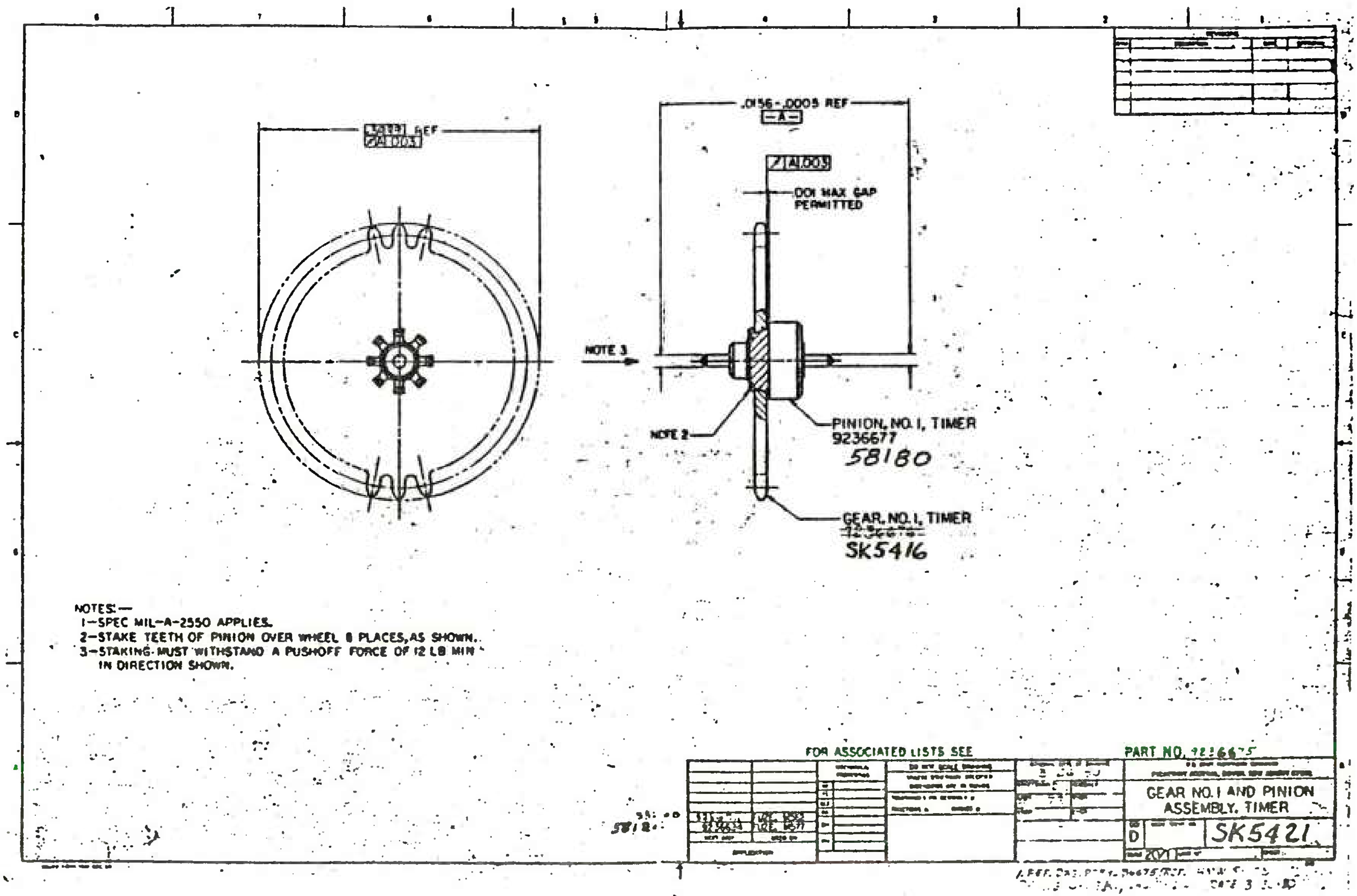
NOTES:

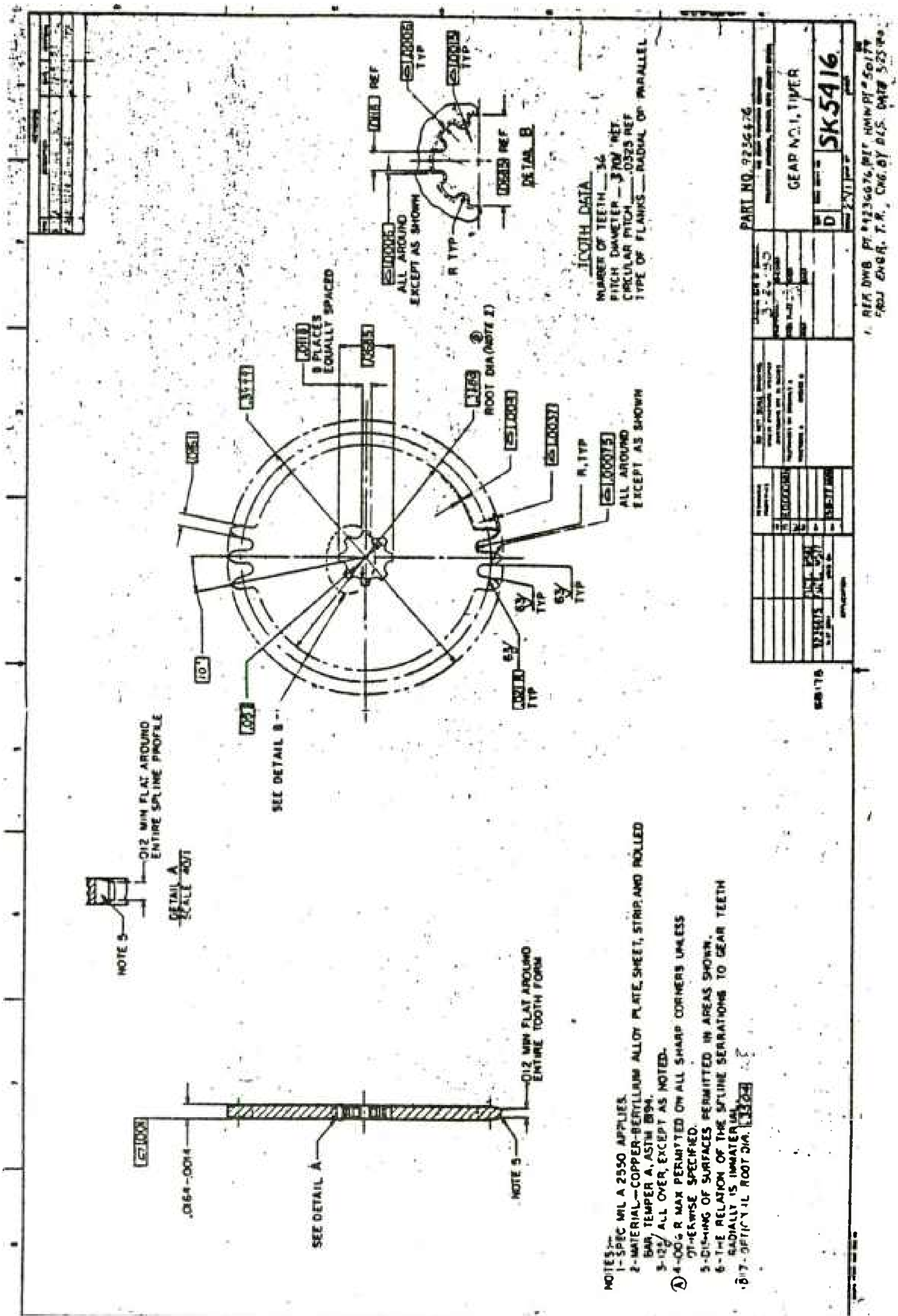
1- SPEC MIL-A-2550 APPLIES.
2- MATERIAL; FREE MACHINING STAINLESS AND HEAT RESISTING STEEL WIRE, TYPE 416 OR 416Se CONDITION A, T, OR H, ~~[illegible]~~, ASTM A581.
3- LONG ADDENDUM INVOLUTE TOOTH FORM. GENERATE USING STANDARD HOB POSITIONED AT .0074 GREATER THAN STANDARD CENTER DISTANCE.(REF.)
4- DRIVE POINT INDENTATIONS ARE PERMISSIBLE ON EITHER FACE. THERE SHALL BE NO RAISED METAL RESULTING FROM THE DRIVE POINT INDENTATIONS.
5- 32/ (ENTIRE TOOTH PROFILE).
6- 125/ ALL OVER, EXCEPT AS NOTED.
7- UNLESS OTHERWISE SPECIFIED FILLETS ARE TO BE .005R. MAX. AND CORNERS ARE TO BE .005R MAX OR .005 MAX. X 45°.

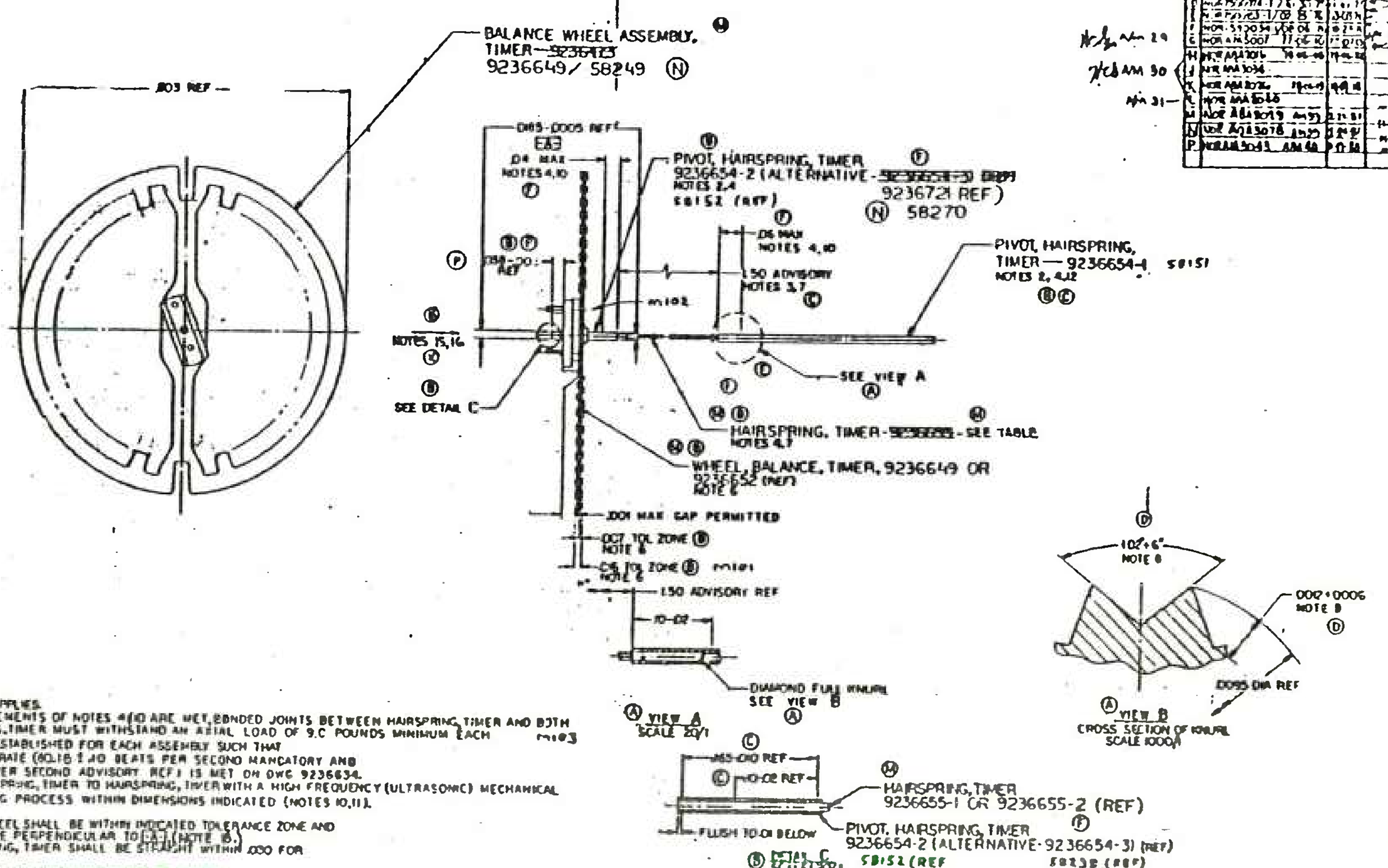




SEE DETAIL A
.0164-.0014
.001
4314
.012 MIN FLAT AROUND ENTIRE TOOTH FORM EXCLUSIVE OF DIEBREAK
9°13'51"
.0161
.096
.4314
SEE DETAIL B
.3814 ROOT DIA
.1157
.028 8 PLACES EQUALLY SPACED
.0037
.004
.0218 TYP
63 TYP
.00075
ALL AROUND EXCEPT AS SHOWN
R TYP
NOTE 5
.012 MIN FLAT AROUND ENTIRE SPLINE PROFILE
DETAIL A
SCALE 50/1
.028 REF
.0006 TYP
.0008
ALL AROUND EXCEPT AS SHOWN
.001 TYP
.005 R. MAX TYP
.1157 REF
DETAIL B
NOTES:-
1- SPEC MIL-A-2550 APPLIES.
2- MATERIAL - COPPER-BERYLLIUM, ALLOY PLATE, SHEET, STRIP AND ROLLED BAR, TEMPER A, ASTM B194.
3- 125/ALL OVER, EXCEPT AS NOTED.
(A) 4- .004 R MAX PERMITTED ON ALL SHARP CORNERS.
5- DISHING OF SURFACES PERMITTED IN AREAS SHOWN.
6- THE RELATION OF THE SPLINE SERATIONS TO GEAR TEETH RADIALLY IS IMMATERIAL.
TOOTH DATA
NUMBER OF TEETH 31
PITCH DIAMETER .4310 REF
CIRCULAR PITCH .0323 REF
TYPE OF FLANKS RADIAL OR PARALLEL
PART NO. 9234679
GEAR, NO 2, TIMER
D
SK 5417
58181
3-26-50


.0156-.0005 REF
-A-
.001 MAX GAP PERMITTED
NOTE 3
NOTE 2
PINION, NO. 1, TIMER
9236677
58180
GEAR, NO. 1, TIMER
SK5416
NOTES:—
1—SPEC MIL-A-2550 APPLIES.
2—STAKE TEETH OF PINION OVER WHEEL 8 PLACES, AS SHOWN.
3—STAKING MUST WITHSTAND A PUSHOFF FORCE OF 12 LB MIN IN DIRECTION SHOWN.
FOR ASSOCIATED LISTS SEE
PART NO.
GEAR NO. 1 AND PINION ASSEMBLY, TIMER
D
SK5421


NOTES:-
1-SPEC MIL A 2550 APPLIES.
2-MATERIAL—COPPER-BERYLLIUM ALLOY PLATE, SHEET, STRIP, AND ROLLED BAR, TEMPER A, ASTM B194.
3-125/ ALL OVER, EXCEPT AS NOTED.
4-.005 R MAX PERMITTED ON ALL SHARP CORNERS UNLESS OTHERWISE SPECIFIED.
5-DISHING OF SURFACES PERMITTED IN AREAS SHOWN.
6-THE RELATION OF THE SPLINE SERRATIONS TO GEAR TEETH RADIALLY IS IMMATERIAL.
TOOTH DATA
NUMBER OF TEETH 36
PITCH DIAMETER .3700 REF
CIRCULAR PITCH .0323 REF
TYPE OF FLANKS RADIAL OR PARALLEL
DETAIL B
DETAIL A
SCALE 40/1
SEE DETAIL A
SEE DETAIL B
NOTE 5
.012 MIN FLAT AROUND ENTIRE SPLINE PROFILE
.012 MIN FLAT AROUND ENTIRE TOOTH FORM
ALL AROUND EXCEPT AS SHOWN
8 PLACES EQUALLY SPACED
ROOT DIA (NOTE 2)
R TYP
REF
TYP
PART NO.
GEAR NO. 1, TIMER
SK5416
D



M20:

NOTES:—

1- SPEC MIL-A-2550 APPLIES.

(F)(B) 2- AFTER THE REQUIREMENTS OF NOTES 4&10 ARE MET, BONDED JOINTS BETWEEN HAIRSPRING, TIMER AND BOTH PIVOTS, HAIRSPRING, TIMER MUST WITHSTAND AN AXIAL LOAD OF 9.C POUNDS MINIMUM EACH

(A) 3- DIMENSION TO BE ESTABLISHED FOR EACH ASSEMBLY SUCH THAT A SPECIFIED BEAT RATE (80.16 ± .10 BEATS PER SECOND MANDATORY AND 80.16 ± .10 BEATS PER SECOND ADVISORY REF) IS MET ON DWG 9236634.

(F)(G) 4- BOND PIVOTS, HAIRSPRING, TIMER TO HAIRSPRING, TIMER WITH A HIGH FREQUENCY (ULTRASONIC) MECHANICAL VIBRATION BONDING PROCESS WITHIN DIMENSIONS INDICATED (NOTES 10,11).

(B) 5-

(H)(E) 6- TIMER BALANCE WHEEL SHALL BE WITHIN INDICATED TOLERANCE ZONE AND THIS ZONE SHALL BE PERPENDICULAR TO -A- (NOTE 6.)

(E) 7- ADVISORY:- HAIRSPRING, TIMER SHALL BE STRAIGHT WITHIN .030 FOR INDICATED LENGTH.

(D) 8- TOOLING REFERENCE DIMENSION, NEED NOT BE GAGED.

(F)(E) 9-

(F) 10- THE REMOVAL OF EXCESS MATERIAL PRODUCED BY BONDING PROCESS PERMITTED WITHIN DIMENSIONS INDICATED.

(F) 11- ADVISORY: RECOMMENDED ASSEMBLY EQUIPMENT, DWG 9236706, MAY BE USED TO PERFORM BONDING PROCESS.

(G) 12- ALTERNATIVE: PIVOT, HAIRSPRING TIMER - 9236654-4 MAY BE USED.

(H) 13- THE REQUIREMENTS OF NOTE 6 ARE OPTIONAL PROVIDED THE REQUIREMENTS OF NOTE 13 ON DWG. 9236635 (58290) ARE MET.

(J) 14- ADVISORY: MATERIAL MAY BE REMOVED FROM TABS TO A .360" RADIUS MAXIMUM TO ASSIST IN POISING THE BALANCE WHEEL ASSY., 9236473 (58293).

(K) 15- PIVOT, HAIRSPRING, TIMER MUST WITHSTAND A PUSHOFF FORCE OF 6 LBS MIN IN DIRECTION SHOWN (NOTE 16).

(K) 16- THE REQUIREMENTS OF NOTE 15 ARE OPTIONAL PROVIDED THE REQUIREMENTS OF DWG. 9236473 (58293), NOTE 5, ARE MET. (L)

(M) 17- ADVISORY:- .020 MAX DIA HOLES MAY BE PLACED ON A .753 DIA ON TAB CENTER LINES, 180° APART TO ADJUST THE BEAT RATE OF THE TIMER ASSEMBLY - 9236634.

1-58290

FOR ASSOCIATED LISTS, SEE 9236647

PART NO. 9236647

BALANCE WHEEL, STAFF AND HAIRSPRING ASSEMBLY, TIMER

F 19203 SK5967

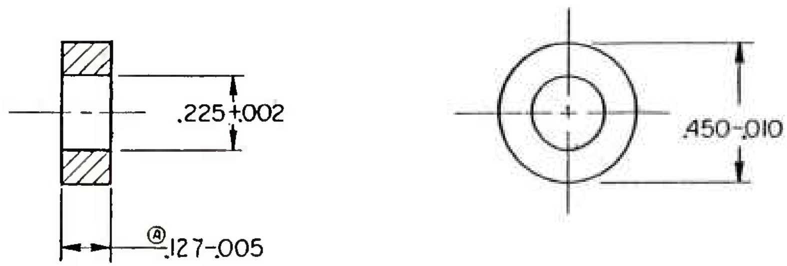
25 AUG 1972

(N) WAS PT# 381560 (REF.)

WAS PT# 58292

DRAWING SIZE C
ARRADCOMR 70-12)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
	[ABA 8811] 7Hd	10 JULY 1979	
D	WAS .152-.005	12-2-83	



NOTES:-
1-SPEC MIL-A-2550 APPLIES.
2-MATERIAL:-ALUMINUM-ALLOY, SHEET AND PLATE, ASTM B209.
3 ALTERNATIVE MATERIAL ALUMINUM-ALLOY BARS, ROD AND WIRES, ASTM B211.

~~582490~~

PART NO. 9236566

NEXT ASSY	USED ON
	FUZE, M582
580580 9236569	FUZE, M577
APPLICATION	

MECHANICAL PROPERTIES: YP, TS, EL2, RA, BH, RH

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

ORIGINAL DATE OF DRAWING 22 DEC 78
DRAFTSMAN | CHECKER
ENGR | ENGR
ENGR | ENGR

U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

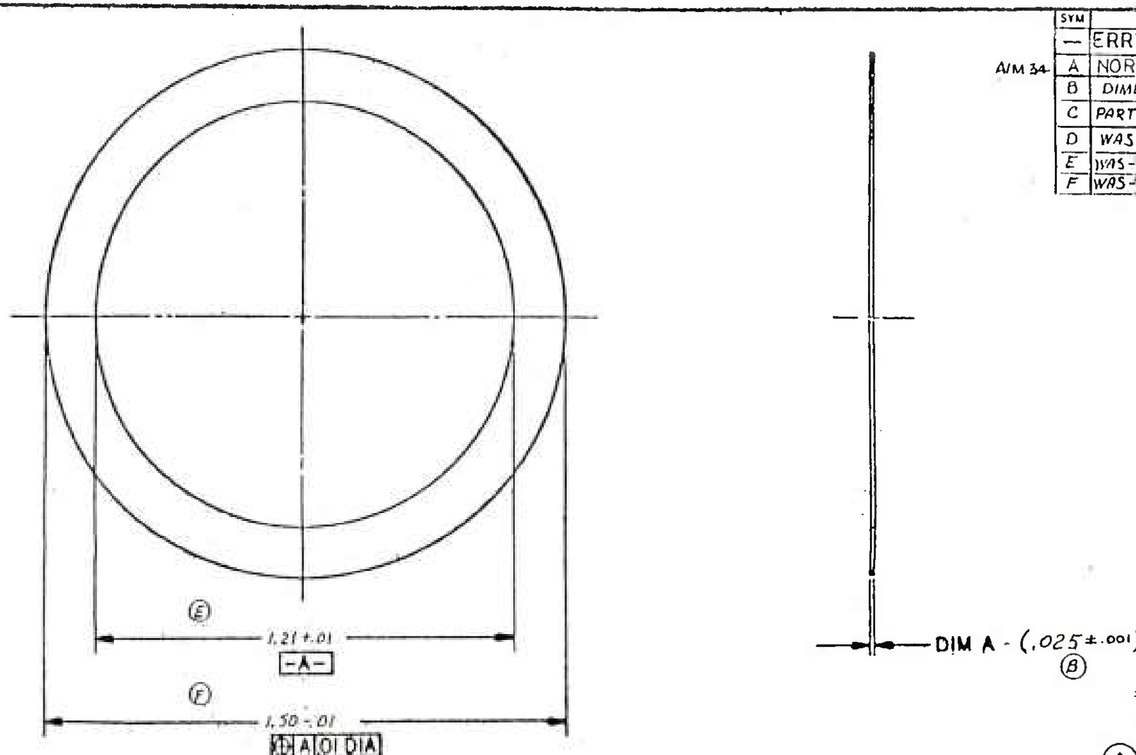
SPACER

SIZE C | CODE IDENT NO 19200 | 9236566
SCALE 4/1 | UNIT WT. | SHEET

SK6216

SYM	DESCRIPTION	DATE	APPROVAL
—	ERR7200346-1 (REL)	08-28-72	
A	NOR ABA3046 780612	780706	
B	DIMENSION ADDED	2·2·84	
C	PART NO., & DIM A REMOVED	2·2·84	
D	WAS SK 6380	2·24·84	
E	WAS 1.211+.008	6·13·84	
F	WAS 1.499-.018	6·15·84	

AIM 34



PART NO.	DIM A
~~9236596-1~~	~~.0050±.0015~~
~~9236596-2~~	~~.0100±.0015~~
~~9236596-3~~	~~.003-.001~~
~~9236596-4~~	~~.0020-.0005~~
~~9236596-5~~	~~.008±.001~~

(A)

NOTES:—
1-SPEC MIL-A-2550 APPLIES.
2-MATERIAL:—STAINLESS AND HEAT-RESISTING CHROMIUM NICKEL STEEL PLATE, SHEET AND STRIP, TYPE 301, ASTM A167.
3-125/ ALL OVER.

ENG.

JUN 13 1984 ~~580660~~

PART NO. SEE TABLE

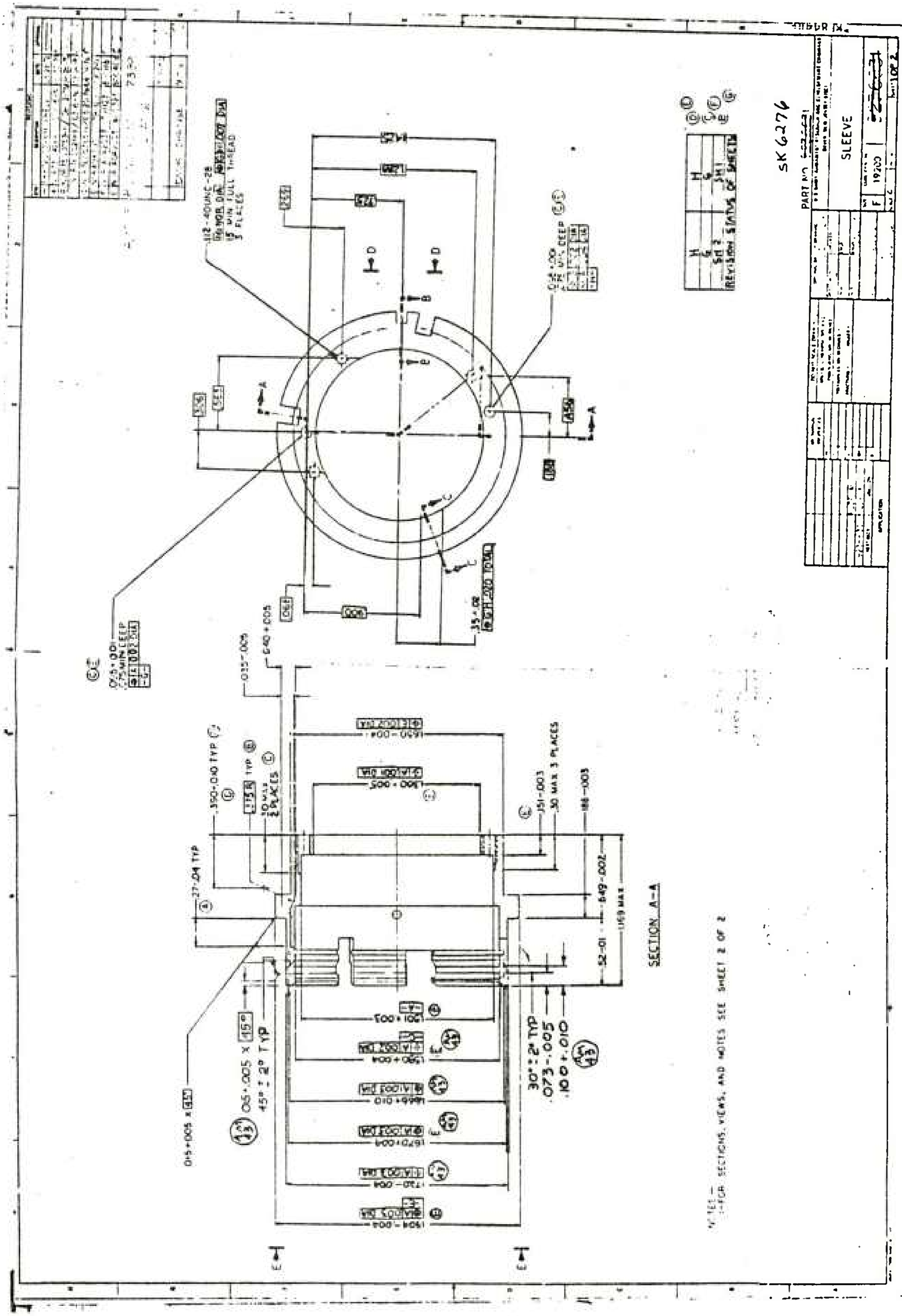
9236569	FUZE M582 FUZE M577	MECHANICAL PROPERTIES YP TS EL2 RA BHI RH	DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± FRACTIONS ± ANGLES ±	ORIGINAL DATE OF DRAWING 28 AUG 1972 DRAFTSMAN / CHECKER ENGR / ENGR ENGR / ENGR
NEXT ASSY	USED ON			
APPLICATION				

U.S. ARMY MUNITIONS COMMAND
PICATINNY ARSENAL, DOVER, NEW JERSEY 07801

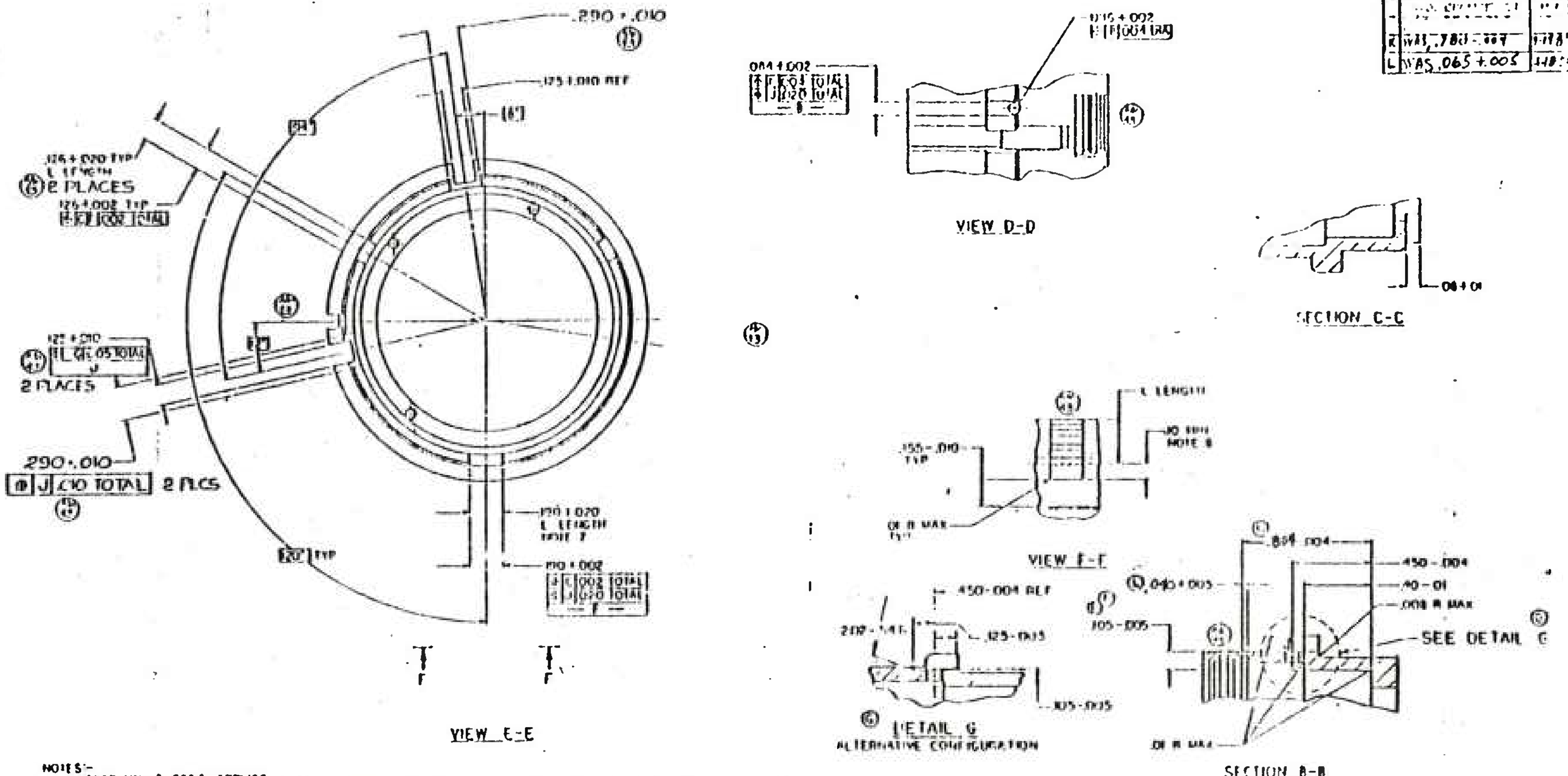
SPACER

SIZE	CODE IDENT NO.	
C	19203	9236596
SCALE 4/1	UNIT WT.	SHEET

(D) SK 6358



NO.1N3 MAY 14 1983



NOTES:-
1- SPEC MIL-A-2550 APPLIES.
2- MATERIAL:-ALUMINUM-ALLOY, DRAWN SEAMLESS TUBES, ALLOY 2024-T3, ASTM B210
3- ALTERNATIVE MATERIAL:-ALUMINUM-ALLOY BARS, RODS AND WIRE, ALLOY 2024-T351, ASTM B211.
4- ALTERNATIVE MATERIAL:-ALUMINUM-ALLOY EXTRUDED BARS, RODS, SHAPES AND TUBES, ALLOY 2014-T6, ASTM B221.
5- ALTERNATIVE MATERIAL:-ALUMINUM-ALLOY, DIE, AND HAND FORGINGS ALLOY 2014-T6, ASTM B247.
6- UNLESS OTHERWISE SPECIFIED FILLETS ARE TO BE .005 R MAX AND CORNERS ARE TO BE .005 R MAX OR .015 MAX X 45° BASIC.
~~7- DIMENSIONS APPLY WHEN PART IS RESTRAINED WITH A .6579 ±.0002 DIA.~~
8- DIMENSION APPLIES TO .126+.002 AND .190+.002 SLOTS.
9- 125/ALL OVER.

K	WAS .780-.004
L	WAS .065 +.005

PART NO.

SLEEVE

19200 9236631

SK 6276 ~~582570~~

DISTRIBUTION LIST

Commander
Armament Research and Development Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-TSS (5)
SMCAR-LCN-T (5)
Dover, NJ 07801-5001

Administrator
Defense Technical Information Center
ATTN: Accessions Division (12)
Cameron Station
Alexandria, VA 22314

Director
U.S. Army Materiel Systems Analysis Activity
ATTN: DRXSY-MP
Aberdeen Proving Ground, MD 21005-5066

Commander
Chemical Research and Development Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCCR-SPS-IL
Aberdeen Proving Ground, MD 21010-5423

Commander
Chemical Research and Development Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCCR-RSP-A
Aberdeen Proving Ground, MD 21010-5423

Director
Ballistic Research Laboratory
ATTN: AMXBR-OD-ST
Aberdeen Proving Ground, MD 21005-5066

Chief
Benet Weapons Laboratory, LCWSL
Armament Research and Development Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-LCB-TL
Watervliet, NY 12189-5000

Commander
U.S. Army Armament, Munitions and Chemical Command
ATTN: AMSMC-LEP-L
AMSMC-TDR(R)
Rock Island, IL 61299-6000

Director
U.S. Army TRADOC Systems Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002